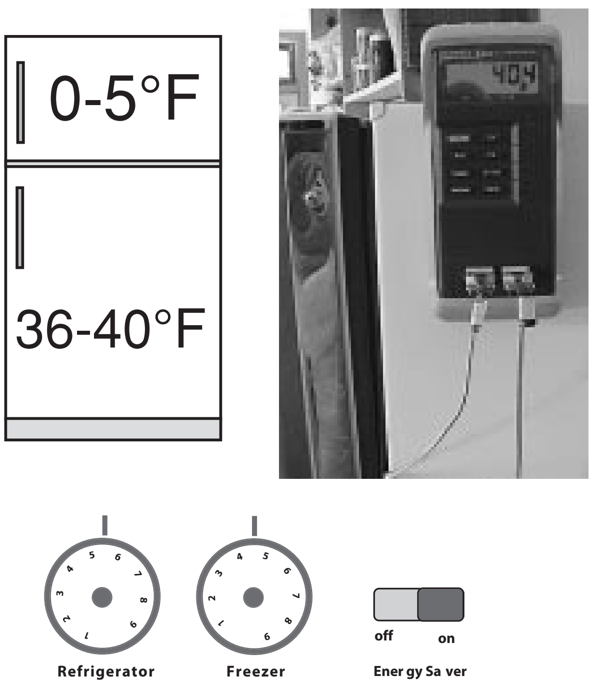
SECTION 4 - APPLIANCES AND LIGHTING

SUBJECTS COVERED IN THIS SECTION

4.1 REFRIGERATOR MEASURES

The quickest way to reduce the consumption many refrigerators and freezers is to adjust the set-points. The refrigerator temperature should be 36–40°F and the freezer should be 0–5°F for optimal energy efficiency. Try the higher end of these temperature ranges to see if these settings are acceptable to the client. If they aren't, instruct the customer to reduce the temperature setting gradually until it is.



Refrigerator settings: Adjust refrigerator and freezer dials to achieve the temperature range shown. Turn the energy-saver switch on if not needed, and explain its operation to the occupants. When the Energy Saver switch is in the "On" position, it saves energy by switching off the door heaters that reduce condensation in humid weather. These heaters aren't needed in dry climates.

REFRIGERATOR ASSESSMENT AND REPLACEMENT

Refrigerators that are more than 10 years old usually consume between 1000 and 2000 kilowatt-hours per year. New ENERGY STAR® rated refrigerators use less than 550 kilowatt-hours per year. Replacement should be considered on a case-by-case basis depending on energy consumption as determined below.

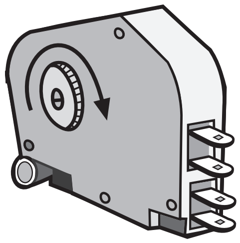
MEASURING REFRIGERATOR ENERGY CONSUMPTION

Since at least two hours are needed to accurately measure refrigerator energy consumption, monitoring is usually performed during an energy audit visit. A recording watt-hour meter is used to measure consumption.

If the refrigerator is an automatic defrost model, an inaccurate reading could result if the unit goes into the electric defrost mode during the test period. This test protocol includes provisions to account for this defrost mode.

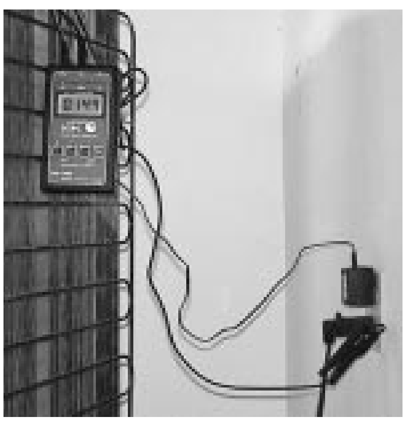
1. Determine if the refrigerator is equipped with automatic defrost. This is usually stated on the manufacturer's data plate or on the outside of the unit. If it is *not* so equipped (manual defrost), proceed to step 3.
2. If the unit is equipped with automatic defrost, locate the defrost timer. This small electrical box is usually located behind the front kick-plate, though you may need to move some wires and use a flashlight to see it. It may also be located on the rear of the unit or inside the main compartment behind the lighting panel.

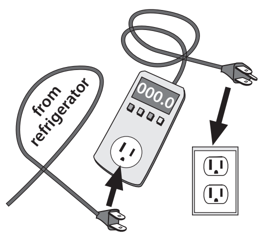
   Open the defrost timer and locate the advance pinion. This shaft usually has a screwdriver slot to allow you to manually advance the timer. Turn the timer clockwise (you can break the timer if you turn counter-clockwise) until you hear a loud click. This turns the defrost heaters on. Turn it 10-20 degrees further until it clicks loudly again, turning the heaters off. You can now perform your measurement since the timer won't call for defrost heat again for several hours.



Defrost control: The defrost control activates electric heaters that melt ice off of the refrigerator coils. It significantly increases the wattage and skews the results of refrigerator testing if it activates during testing.

3. Connect the refrigerator to a recording watt-hour meter. Run the test for at least two hours. You don't need to stop at exactly two hours, and a longer measurement is O.K. During the test, avoid opening the refrigerator, or do so briefly.





Kilowatt-hour meters: Follow the manufacturer's instructions for connection carefully

4. At the end of the test, read the kilowatt/ hours of consumption measured by the meter. Divide this number by the number of hours in the test. This gives you the number of kilowatts consumed each hour. Multiply this number times the total number of hours in a year (8760 hours per year).The product of this calculation is the annual kilowatt-hours expected to be consumed by the unit.

length of test in hours

number of hours in a year

0.32 ÷ 2 = 0.16 x 8760 = 1402

kilowatt-hours consumed

hourly consumption in watts

predicted annual consumption in kilowatt-hours

Refrigerator consumption example: In this example, a 2-hour measurement was performed. During this time, the appliance consumed 0.32 kilowatt-hours of electricity, or 0.16 watts for every hour. The annual total of 1402 kilowatt-hours is well beyond the 550 kilowatt-hours per year consumed by today's most efficient refrigerators.

The American Home Appliance Manufacturers (AHAM) also publishes a list of refrigerators by year manufactured, model, serial number, and approximate annual electricity consumption. Consulting this list is also a good way to estimate the cost effectiveness of refrigerator replacement.

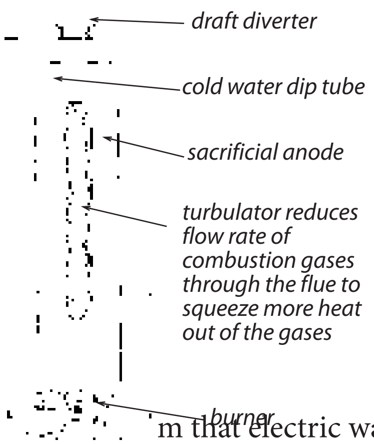
Refrigerators that are replaced should be taken to a facility, licensed to reclaim their refrigerant. No refrigerator that is taken out of service should be returned to service by sale, barter, or for free.

Cleaning condenser coils: If the refrigerator will remain, brush the dust from its condenser coils to improve airflow and heat transfer.

4.2 DOMESTIC HOT WATER SYSTEMS

Observe the following general specifications for domestic water heaters.

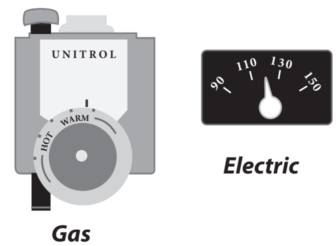
- ✔ Confirm that the water heater has a pressure-and-temperature relief valve and a safety discharge pipe. The discharge pipe should terminate 6 inches above the floor or outside the dwelling as specified by local codes. The discharge pipe should be made of rigid metal pipe or approved high temperature plastic pipe.



Standard gas water heater: This open combustion appliance is often troubled by spillage and backdrafting.

- ✔ ...m that electric water heaters are serviced by a dedicated electrical circuit.
- ✔ Adjust water temperature with clients' approval to 115°-120°F. If the home has a older automatic dishwasher without its own water-heating booster, set the thermostat to 140°F. Shut off power to electric water heaters before opening the access panels.
- ✔ Inspect faucets for hot water leaks and repair leaks if needed.

Setting hot-water temperature: Getting the temperature between 115 and 120°F can take a few adjustments and temperature measurements.



WATER HEATER BLANKETS

Install an insulation blanket on all heaters that are outside the heated space, unless the manufacturer's label prohibits it. Follow these guidelines to avoid fire hazards and to simplify future service.

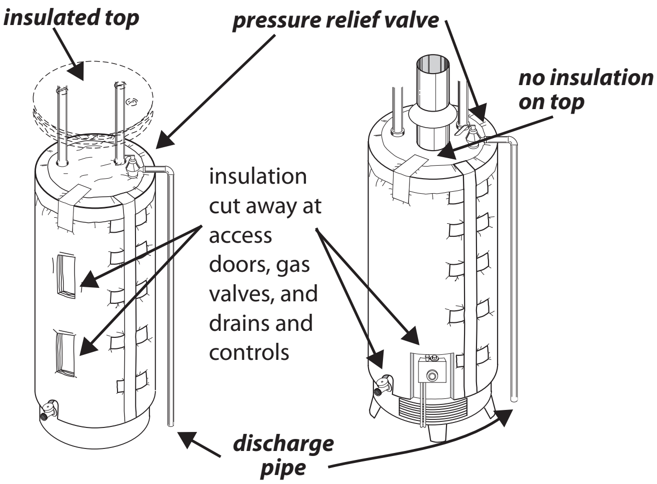
Gas water heaters

- ✔ Keep insulation at least 2 inches away from the gas valve and the burner access panel. Do not install insulation below the burner access panel.
- ✔ Do not cover the pressure relief valve.
- ✔ Do not insulate the tops of gas- or oil-fired water heaters to avoid obstructing the draft diverter.

Electric water heaters

- ✔ Cut the blanket around the thermostat and heating element access plates, or cover the plates and mark their location on the insulation facing.
- ✔ Do not cover the pressure relief valve.

✔ Cover the top of the water heater with insulation if it doesn't obstruct the pressure relief valve.



Water heater insulation: Insulation should be installed carefully so it doesn't interfere with the burner, elements, draft diverter, or pressure relief valve.

Hot water pipe insulation

Perform these measures to slow convection of hot water into the water lines near the tank.

✔ Insulate the first 6 feet of both hot and cold water pipes. Use the correct size of insulation sleeve.

✔ Cover elbows, unions and other fittings to same thickness as pipe.

✔ Keep pipe insulation at least 6 inches away from the flue of gas or oil water heaters.

Water heater replacement

Existing gas water heaters typically use 250 or more therms per year. New gas water heaters use as little as 175 therms per year. A savings of 75 therms can repay the initial investment in 4-to-9 years at today's gas costs.

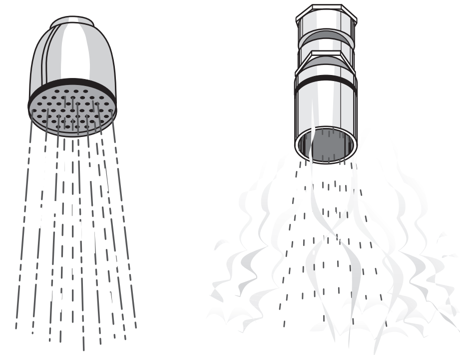
Any replacement gas or oil water heater should have an energy factor of at least 0.62 or have a minimum of 2 inches of foam insulation. Replacement water heaters should be wrapped with external insulating blankets for additional savings.

In tight homes or homes where the mechanical room is located in living areas, replacement gas or oil water heaters should be either power-draft or sealed-combustion units. Sealed-combustion water heaters are preferred in homes where the water heater is installed in a living space.

If the existing electric water heater must be replaced, the new unit should have an energy factor of at least 0.88 and be equipped with at least three inches of foam insulation.

Water-saving shower heads

Most families use more hot water in the shower than for any other use. A low-flow shower head reduces this consumption.



Water-saving shower heads: The showerhead on the right uses less water and so reduces water heating expense.

You can determine the output of an existing shower head by measuring the time it takes to fill a one-gallon plastic milk jug. Cut out the top to fit over the shower head, and turn on the water to full volume. If the jug fills in less than 20 seconds, the flow rate is more than 3 gallons per minute.

Replace high-flow shower heads with a water-saving shower head rated for a flow of 1.5 to 2.5 gallons per minute. Avoid installing the cheapest shower heads as they often provide a less satisfying shower and are prone to clogging.

Use caution in removing the existing shower head from old, fragile plumbing systems. Do not attempt to remove the neck that connects the shower head to the fitting inside the wall, but replace just the showerhead itself.

4.3 Lighting Measures

Most homes have 6-to-12 lamps that burn for more than two hours per day. These should be considered for retrofit by more-efficient compact fluorescent lamps (CFLs). This easy retrofit has as good an economic return as any weatherization measure.

Compact fluorescent lamps are still a little bigger than the incandescents they replace. In many fixtures there is extra room and the size difference isn't an issue. In other fixtures, standard-sized compact fluorescents won't fit. To address this size problem, the lighting industry has recently created a smaller size of compact fluorescent lamp known as sub-compact fluorescent. A weatherization agency would be wise to stock both the more common and less expensive compact fluorescents and also the more expensive and versatile sub-compact models.

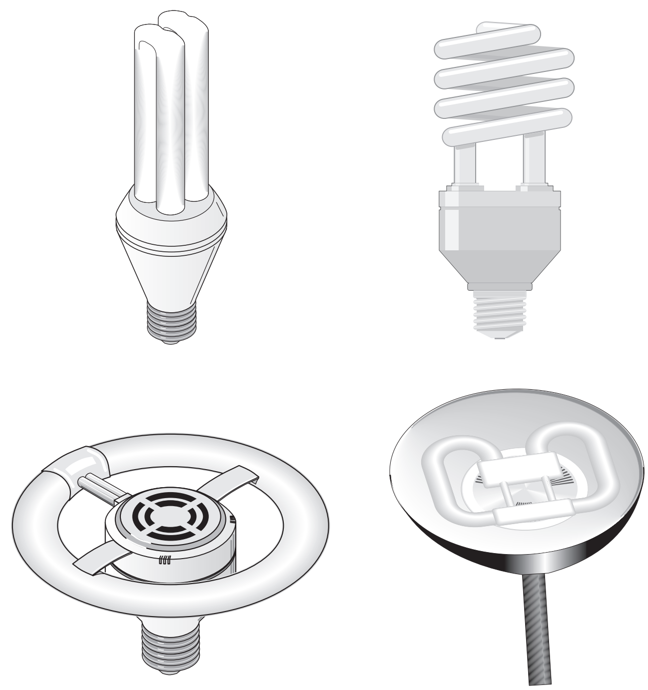
CFLs consume about one-quarter to one-third the energy of conventional incandescent lamps. Use the table here, or one similar, to determine the size of lamps you use for replacements.

Table 4.3.1: CFL Replacement Sizes

Existing incandescent		Replacement CFL
Wattage	Output (lumens)	Wattage
25	375	9
40	500	11
60	800	15
75	1200	18-20
100	1650	23-27

Do not install CFLs in fixtures that are controlled by solid-state dimmers or timers, unless the manufacturer's literature specifically allows this. You can install CFLs in fixtures controlled by mechanical countdown timers – the type that you twist to wind up for a certain period of time.

Replace as many incandescents as your program allows. Explain the benefits to the client, and encourage them to purchase additional CFLs if possible. Point out that the long life of these lamps makes them economical despite their higher initial cost.



Compact fluorescent lamps: These advanced lamps use about one-quarter to one-third of the electricity of the incandescent lamps they usually replace, and they last about ten times as long.

4.4 LAUNDRY EQUIPMENT

New clothes washers are up to 5 times as efficient in the use of energy and water as existing units.

Clothes dryers haven't experienced the same dramatic increase in efficiency and are less cost-effective to replace. Over time lint collects in the vent, elements, and air passageways reducing airflow and increasing cycle time, making maintenance the most important energy-saving measure.

Clothes washer measures

- ✔ Replace vertical-axis clothes washers with horizontal-axis units if your program allows.

Clothes dryer measures

The drying time of a load of laundry is determined by the dryer installation and the amount of lint in the dryer, vent piping, and vent termination. After a few years, lint builds up and slows drying time, increasing energy use and electricity cost. The original installation can also cause excessive drying time when vents are excessively long, kinked, or restricted in some other way.

Observe the following suggestions when servicing clothes dryers to reduce drying time and improve energy efficiency. Unplug the clothes dryer before performing these measures.

- ✔ Remove the vent pipe and vent termination and clean all lint out of them.
- ✔ Clean lint out of the electric heating elements and the airway around them.
- ✔ Inspect the airway at the dryer's vent connection and clean lint out of it.
- ✔ Replace dryer vents longer than 3 feet with 4-inch-diameter rigid aluminum or galvanized pipe.
- ✔ Avoid using screws to join rigid pipe sections because they collect lint. Join and seal the sections with silicone caulking.
- ✔ Dryer vents longer than 6 feet should use a 5-inch dryer vent termination and 5-inch-diameter rigid vent pipe.
- ✔ Use short, stretched pieces of flexible dryer vent to connect the dryer to the rigid vent if needed to allow dryer to be moved in and out.
- ✔ If you find flexible dryer vents that are longer than necessary, stretch the flexible pipe and cut it just long enough to allow the dryer to slide in and out of its resting place.

Rigid metal vent pipe: The preferred venting system is shown here. Flexible vent has more airflow resistance, collects more lint, and makes the dryer less efficient.

Lint filters: Most but not all lint is caught in the lint filter. Lint also collects in the elements and exhaust piping, reducing the dryer's efficiency over time.

Customer education for laundry use

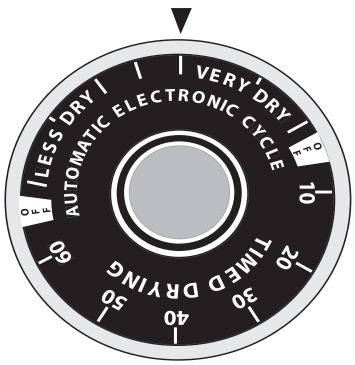
- ✔ Wash clothes in cold water unless warm or hot water is needed to get dirty clothes clean.
- ✔ Wash and dry full loads of clothes.

✔ Cleaning the dryer lint filter after each cycle minimizes drying time.

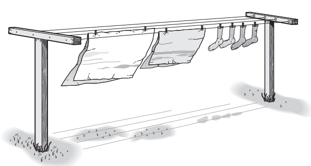
✔ Drying clothes on a line is the best way to reduce clothes-drying costs.

✔ Remove lint and outdoor debris from the dryer vent termination regularly.

✔ Use the electronic cycle. Note the dial reading that gets clothes acceptably dry and use that setting consistently.



The electronic cycle uses a heat or humidity sensor to sense dryness instead of a person choosing an approximate time, which may be too long.



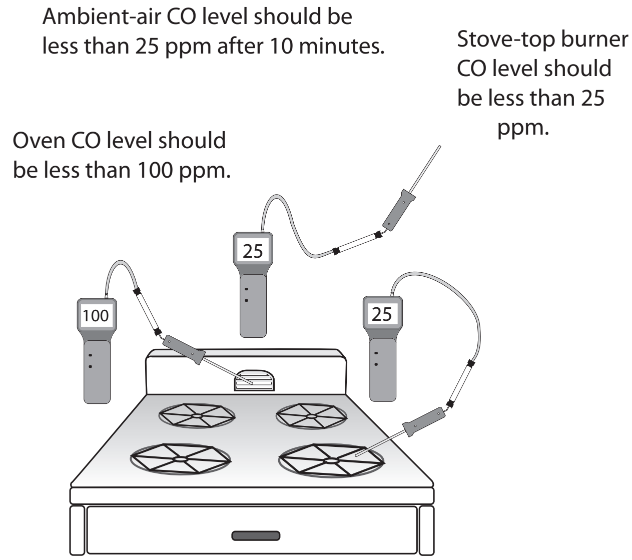
Using clothes lines during dry weather can save energy and reduce electric peak load.

4.5 GAS RANGE AND OVEN SAFETY

Gas ranges and ovens can produce significant quantities of CO in a kitchen. Overfiring, dirt buildup, and foil installed around burners are frequent causes of CO. Oven burners are likely to produce CO even when not obstructed by dirt or foil. Test the range and oven for safety following these steps and take the recommended actions before or during weatherization.

1. Test each stove-top burner separately, using a digital combustion analyzer or CO meter and holding the probe about 8 inches above the flame.
2. Clean and adjust burners producing more than 25 parts per million (ppm). Burners often have an adjustable gas control.
3. Turn on the oven to bake at high temperature. Sample the CO level in exhaust gases at the oven vent and in the ambient air after 10 minutes.
4. Actions include cleaning the oven, removing aluminum foil, or adjusting the burner's adjustable gas control.
5. If the CO reading is over 100 ppm or if the ambient-air reading rises to 25 ppm or more during the test, abort the test.

Most range and oven burners are equipped with adjustable needle-and-seat valves. Most ranges also have an adjustable gas regulator that services the entire unit.



SECTION 5 - AIR SEALING AND INSULATION

SUBJECTS COVERED IN THIS SECTION

5.1 DUCT LEAKAGE

Duct leakage may or may not be a significant energy and comfort problem, depending on where the ducts are located. If the ducts are located completely within the conditioned living space of a home, duct leakage is probably a minor problem.

If the ducts are located in an attic, crawl space, attached garage, unheated basement, or leaky floor cavity, duct leakage can be a major energy problem. The question then becomes "How much duct leakage is there and how much time and money can be spent to seal the ducts to an acceptable leakage standard?"

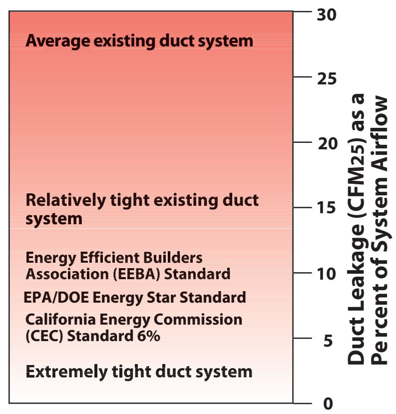
If existing ducts are located outside the home's thermal boundary, it's a safe bet that sealing their leaks will be cost-effective, assuming you don't have to perform demolition to find them.Test existing ducts for an assessment of the quantity of air leakage and how much effort and money sealing will require. Testing also helps measure success and gives technicians valuable feedback.

DUCT AIR-TIGHTNESS STANDARDS

Duct air leakage is a major energy-waster in homes where the ducts are located outside the home's thermal boundary in a crawl space, attic, attached garage, or leaky basement. When the weatherization job will leave these intermediate zones outside the thermal boundary, duct air-sealing is cost-effective.

Ducts should be tested to determine how much they leak before any duct air sealing is performed.

For information on duct airtightness testing see *See Section 2.6 and Section 2.7.*

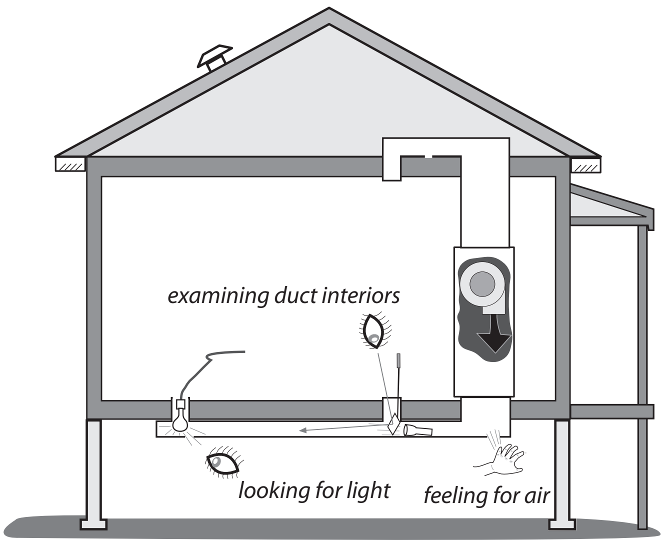


Duct leakage standards: Dividing the tested duct leakage in CFM_{25} by the assumed system airflow of 400 CFM per ton provides the most common type of duct-leakage standard.

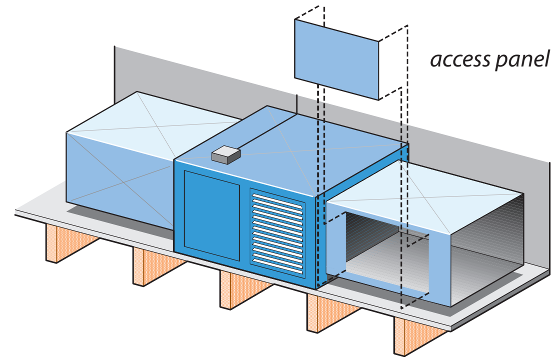
FINDING DUCT LEAKS USING TOUCH AND SIGHT

One of the simplest ways of finding duct leaks is feeling with your hand for air leaking out of supply ducts, while the ducts are pressurized by the air handler's blower. Duct leaks can also be located using light. Here are three different tests used to locate air leaks.

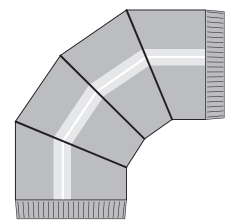
1. Use the air handler blower to pressurize supply ducts. Closing the dampers on supply registers temporarily or partially blocking the register with pieces of carpet, magazines, or any object that won't be blown off by the register's airflow will increase the duct pressure and make duct leaks easier to find.
2. Place a trouble light, with a 100-watt bulb, inside the duct through a register. Look for light emanating from the exterior of duct joints and seams.
3. Recognize which duct joints were difficult to fasten and seal during installation. These joints are likely duct-leakage locations.



Finding duct air leaks: Finding the exact location of duct leaks precedes duct air-sealing.



Plenums, poorly sealed to air handler: When air handlers are installed in tight spaces, plenums may be poorly fastened and sealed. Cutting a hole in the duct may be the only way to seal it.



Sectioned elbows: Joints in sectioned elbows known as gores are usually quite leaky and require sealing with duct mastic.

Feeling air leaks establishes their exact location. Ducts must be pressurized in order to feel leaks because you can't usually feel air leaking into depressurized ducts.

A trouble light, flashlight, and mirror help you to visually understand duct interiors so that you can plan an air-sealing procedure.

Duct sealing

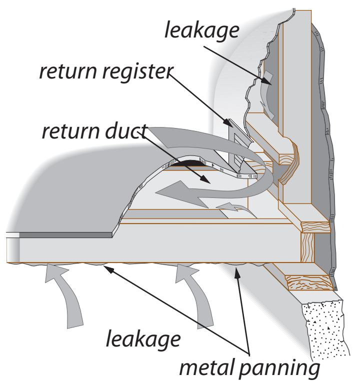
Ducts located outside the thermal boundary or in an intermediate zone like a ventilated attic or crawl space should be sealed. The following is a list of duct-leak locations in order of their relative importance. Leaks nearer to the air handler see higher pressure and are more important than leaks further away.

- ✔ First, seal all return leaks within the combustion zone to prevent this leakage from depressurizing the combustion zone and causing backdrafting.
- ✔ Plenum joint at air handler: These joints may have been difficult to fasten and seal because of tight access. Go the extra mile to seal them airtight by caulking this important joint even if it requires cutting an access hole in the plenum. (Avoid mastic and fabric mesh here for future access—furnace replacement, for example.)
- ✔ Joints at branch takeoffs: These important joints should be sealed with a thick layer of mastic. Fabric mesh tape is a plus for new installations or when access is easy.
- ✔ Joints in sectioned elbows: Known as gores, these are usually leaky.
- ✔ Tabbed sleeves: Attach the sleeve to the main duct with 3-to-5 screws and apply mastic plentifully.
- ✔ Flexduct-to-metal joints: Apply mastic to the metal sleeve. Clamp the flexduct's inner liner over this strip of mastic with a plastic strap, using a strap tensioner. Clamp the insulation and outer liner with another strap.
- ✔ Support ducts and duct joints with duct hangers where needed.
- ✔ Seal leaky joints between building materials composing cavity-return ducts, like panned floor cavities and furnace return platforms.

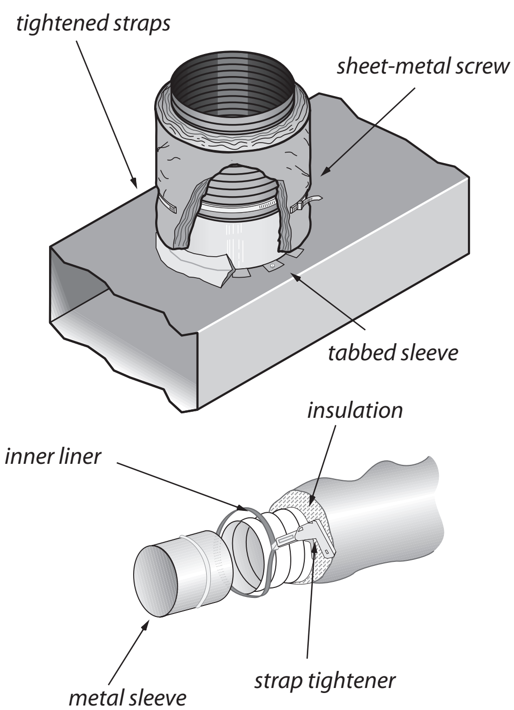
✔ Seal leaky joints between supply and return registers and the floor, wall, and ceiling to which they are attached.

✔ Consider sealing off supply and return registers in unoccupied basements.

✔ Seal penetrations made by wires or pipes traveling through ducts. Even better: move the pipes and wires and patch the holes.



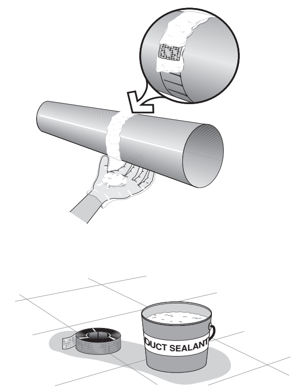
Panned floor joists: These return ducts are often very leaky and may require removing the panning to seal the cavity.



Flexduct joints: Flexduct itself is usually fairly airtight, but joints, sealed improperly with tape, can be very leaky. Use methods shown here to make flexduct joints airtight.

Materials for duct air-sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply at least $^1/_{16}$-inch thick and use reinforcing mesh for all joints wider than $^1/_8$ inch or joints that may experience some movement.



Duct mastic: Mastic, reinforced with fabric webbing, is the best choice for sealing ducts.

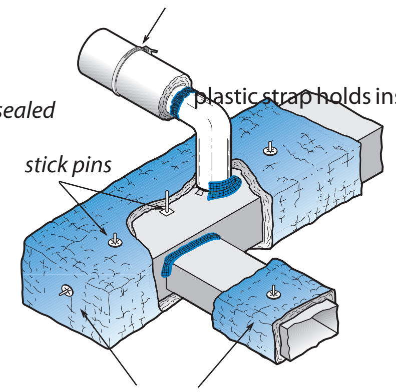
Siliconized acrylic-latex caulk is acceptable for sealing joints in panned joist spaces, used for return ducts.

Joints should rely on mechanical fasteners to prevent joint movement or separation. Tape should never be expected to hold a joint together nor expected to resist the force of compacted insulation or joint movement. Aluminum foil or cloth duct tape are not good materials for duct sealing because their adhesive often fails after a short time.

Duct Insulation

Insulate supply ducts that run through unconditioned areas outside the thermal boundary such as crawl spaces, attics, and attached garages with a minimum of R-6 vinyl- or foil-faced duct insulation. Don’t insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer. Follow the best practices listed below for installing insulation.

- Always perform necessary duct sealing before insulating ducts.



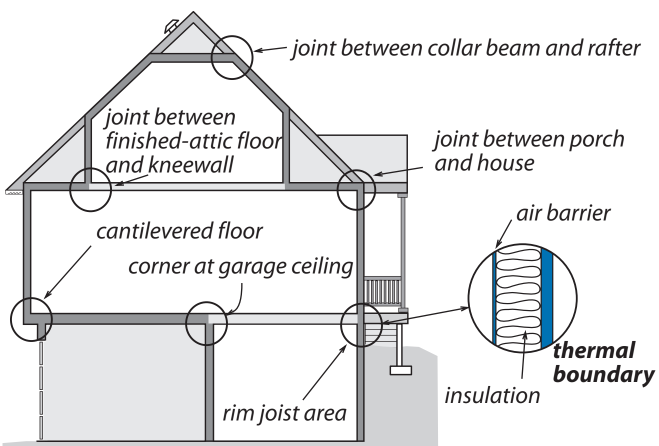
Duct insulation: Supply ducts, located in unheated areas, should be insulated to a minimum of R-6.

- Insulation should cover all exposed supply ducts, without significant areas of bare duct left uninsulated.
- Insulation should be fastened by mechanical means such as stick pins, twine, or plastic straps. Tape can be effective for covering joints in the insulation to prevent air convection, but tape will usually fail if expected to resist the force of the insulation's compression or weight.

5.2 BUILDING SHELL AIR SEALING

Air sealing and insulating improve the building's thermal boundary. This boundary should consist of an air barrier that is located immediately adjacent to the insulation. Perform air-leakage testing and evaluation before beginning air-sealing or insulation work. *See section 2.2.*

Use visual inspection and/or pressure diagnostics to determine the cost-effectiveness of improving the thermal resistance of a building. Both air sealing and adding insulation use the same general approach–the most critical areas are retrofitted first and then less needy areas are retrofitted as time and budget permit.



Thermal boundary flaws: The thermal boundary contains the air barrier and insulation, which should be adjacent to one other. The insulation and the air barrier are often discontinuous at corners and transitions. These areas merit special attention.

Reducing air leakage accomplishes several tasks.

- Saves energy by protecting the thermal resistance of the shell insulation
- Increases comfort by reducing drafts and moderating the radiant temperature of interior surfaces
- Reduces moisture migration into building cavities

Air travels into and out of the building by three main pathways.

- Major air leaks, which are significant flaws in the home's air barrier
- Minor air leaks, which are often seams between building materials
- Through the building materials themselves (*See table 2.5.1.*)

WHEN NOT TO AIR SEAL

Air sealing reduces the exchange of fresh air in the home, and can alter the pressure balance within the home. Before air sealing, survey the home to identify both air-pollutants that may be concentrated by air sealing efforts, and combustion appliances that may be affected by changes in house pressure.

Don't perform air-sealing when there are obvious threats to the occupants' health, the installers' health, or the building's durability. If any of the following circumstances are present, do not perform air sealing until they are corrected.

- Fire hazards
- Measured carbon monoxide levels that exceed the suggested action level
- The building is already at or below its Building Tightness Limit, and no mechanical ventilation exists or is planned
- Combustion-zone depressurization that exceeds -4 pascals during a worst-case test
- Combustion appliances whose chimneys don't meet minimum standards
- Unvented space heaters that will be used after air-sealing work
- Moisture that has caused structural damage such as rot, mold, or mildew
- Infestations, vermin, or other sanitary issues

Sealing major air leaks and bypasses

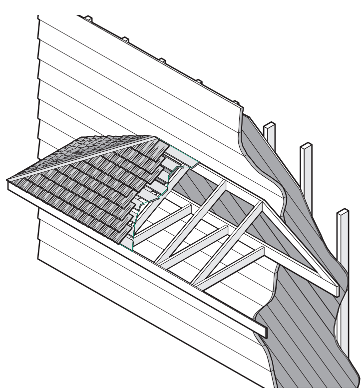
Major air sealing involves finding and sealing large openings that admit outdoor air into the conditioned space. Sealing major air leaks is one of the best energy-saving measures.

Major air sealing activities are generally completed prior to other shell measure activities, and should result in a significant drop in the blower door reading and/or changes in pressure diagnostics readings.

Bypasses are conduits for air travel within building cavities. Bypasses don't always allow outdoor air into the home, but may allow outdoor air to circulate around within the building cavities. They can be a significant energy loss, however, when they are adjacent to interior surfaces of the home that can conduct heat into or out of the home. Bypasses and major air leaks are often found in combination with one another, with some air leaking through the air barrier and some staying within the building cavities.

Bypasses that don't penetrate the air barrier won't have an impact on pressure diagnostic tests, but they should still be sealed to reduce conductive losses (through interior surfaces) and to limit the condensation that can take place on cold interior surfaces.

Major air leaks will often be found between the conditioned space and intermediate zones such as floor cavities, attics, crawl spaces, attached garages, and porch roofs. The time and effort you spend to seal major air leaks should depend on its size.



Porch air leakage: Porch roof cavities often allow substantial air leakage because of numerous joints, and because there may be no siding or sheathing installed in hidden areas.

Major air leaks are not always easily accessible. When they are hard to reach, technicians sometimes blow dense-packed cellulose insulation into surrounding cavities, hoping that the cellulose will resist airflow and plug cracks between building materials.

Air sealing tips

Air barriers must be able to resist severe wind pressures. It is always preferable to use strong air-barrier materials like plywood, drywall, or foamboard to seal major air leaks, particularly in regions with strong winds. These materials should be attached with mechanical and/or adhesive bonds.

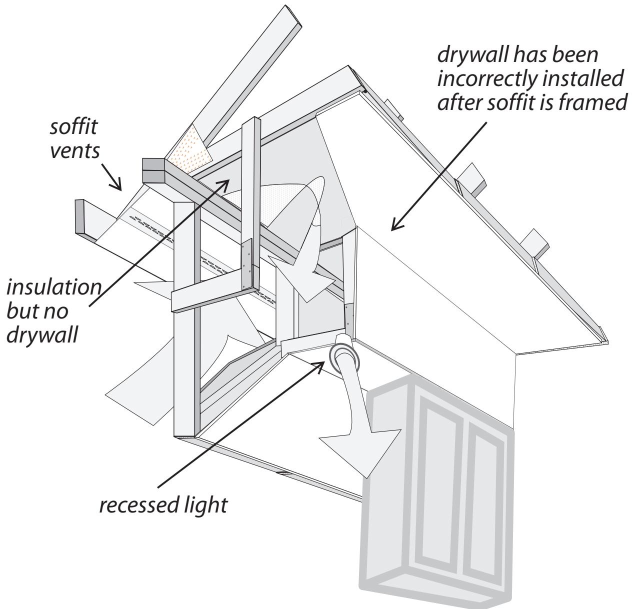
Caulk should only be used for sealing very small cracks. Use liquid foam for cracks larger than 1/4". Don't leave any type of foam exposed to sunlight.

Seal all air leaks and bypasses prior to insulating except where cellulose is also being used for sealing.

Joist cavities under knee walls in finished attic areas:

Connect knee wall with the plaster ceiling of the floor below by creating a rigid seal under the knee wall.

Kitchen or bathroom interior soffits: Seal the top of the soffit with fire-rated foil-faced foam board, plywood or drywall, fastened and sealed to ceiling joists and soffit framing.

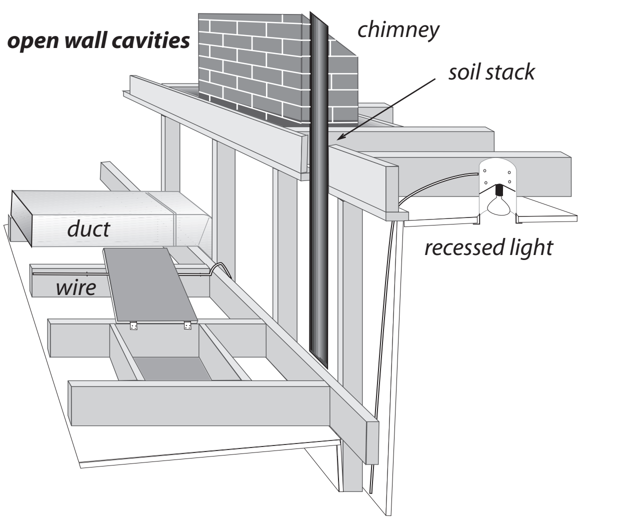


Kitchen soffits: These framing flaws are often open to both the wall cavity and ventilated attic. Any hole in the soffit creates a direct connection between the kitchen and attic.

Soil stacks, plumbing vents, open plumbing walls:

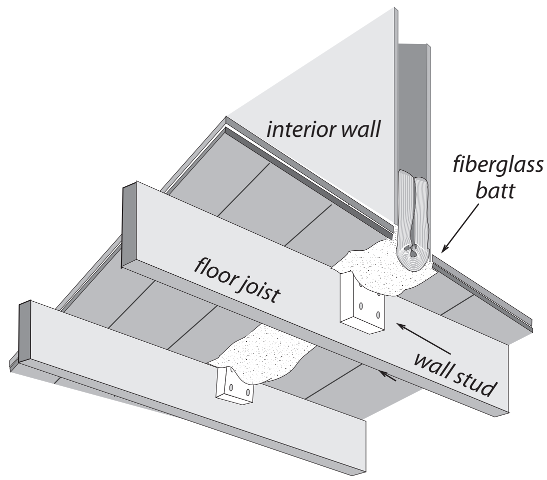
Seal joints with expanding foam or caulk. If joint is too large, stuff with fiberglass insulation, and spray foam over the top to seal the surface of the plug.

Two-level attics in split-level houses: Seal the wall cavity with a rigid material fastened to studs and wall material.



Two-level attic: Split-level homes create wall cavities connected to the ventilated attic. Other air leaks shown are duct, recessed light, and chimney.

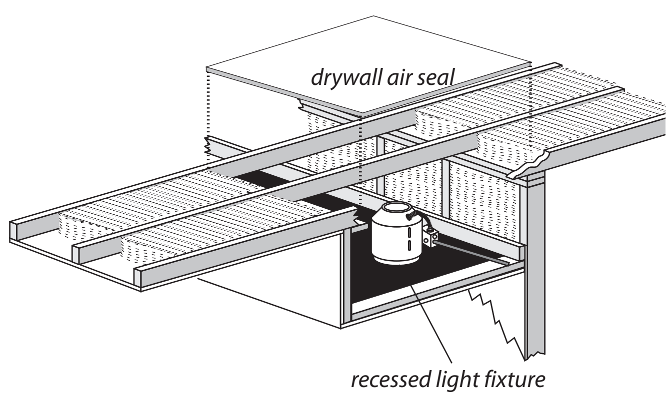
Tops and bottoms of balloon-framed interior partition wall cavities, missing top plates: Seal with a fiberglass insulation plug, covered with a 2-part foam air seal. Seal with rigid barrier, such as $^1/_4$-inch plywood or 1-inch foam board sealed to surrounding materials with caulk or liquid foam.



Balloon-framed interior walls: These wall cavities can be open to both the attic and basement.

Masonry chimneys: Seal chimney and fireplace bypasses with sheet metal (minimum 28 gauge thickness). Seal to chimney or flue and ceiling structure with a high temperature sealant or chimney cement.

Housings of exhaust fans and recessed lights: Caulk joints where housing comes in contact with the ceiling with high-temperature silicone sealant.



Recessed light fixtures: These are major leakage sites, but these fixtures must remain ventilated to cool their incandescent bulbs. Plug the top of the soffit in this case with drywall.

Duct boots and registers: If ducts are located in attic, crawl space, attached garage, or in the floor cavity above garage, caulk or foam the joint between the boot and the ceiling, wall, or floor.

Duct chases: If chase opening is large, seal with a rigid barrier such as fire-rated foam board, plywood or drywall, and seal the new barrier to ducts with caulk or foam. Smaller cracks between the barrier and surrounding materials may be foamed or caulked.

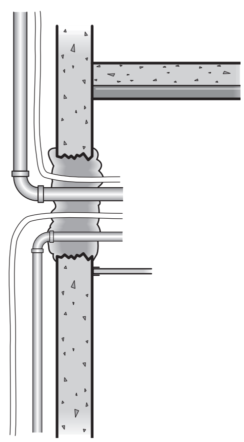
Bathtubs and shower stalls: Seal holes and cracks from underneath with expanding foam. Seal large openings with rigid materials caulked or foamed at edges.

Attic hatches and stairwell drops: Weatherstrip around doors and hatches. Caulk around frame perimeter.

Wiring and conduit penetrations:

Seal penetration with caulk or foam.

Other openings in the air barrier: Seal with rigid material, caulk, spray foam, or expanding foam depending upon size and nature of opening.



Large holes: Tradesmen often knock large holes in concrete walls without patching them. These can create large air leaks.

Pocket door cavities: When located on the second floor, cap the top of the entire wall cavity in the attic with rigid board, caulked and stapled. Where wall cavities containing the retracted pocket door halves connect with exterior framed walls, stuff narrow strips of unfaced fiberglass batts into the door opening with a broom handle far enough to allow for complete opening of the door.

Minor air sealing

Minor air sealing includes sealing small openings with such materials as caulk, weather stripping, or sash locks. These measures tend to please the home's occupants by reducing perceived drafts, slowing the entry of dirt, or making the interior paint look better. But they rarely result in significant blower door reductions or changes in pressure diagnostic readings.

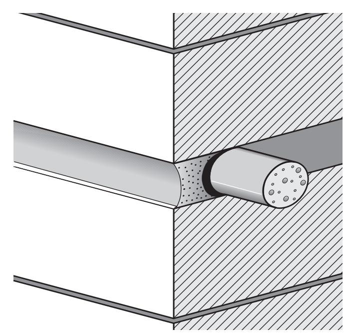
Cracks in exterior window and door frames: Sealing serves to keep bulk water out. If the crack is deeper than $^{5}/_{16}$-inch, it should be backed with a material such as backer rod and then sealed with caulk. Any existing loose or brittle material should be removed before the crack is recaulked.

Joints in foundation sill plate: They can be sealed with caulk or foam.

Holes and cracks in masonry surfaces: Best sealed with a cement-patching compound or mortar mix.

Interior joints:

These can be caulked if blower door testing indicates substantial leakage. These joints include where baseboard, crown molding and/or casing meet the wall/ceiling/floor surfaces. Gaps around surface-mounted or recessed light fixtures and ventilation fans can be caulked if needed.



Backer rod: Use it to support caulk when sealing large uniform gaps. Use

Air-sealing multi-family buildings

Large multi-family buildings present some unique air sealing issues to weatherization crews. Air moves in large older buildings through passages formed by construction features such as furring strips on exterior walls, duct chases, chimneys, and plumbing stacks.

Experience has shown that large air leaks and bypasses must be sealed from the attic, not from inside the house, because there are just too many openings to seal once air enters walls, floors, and chases.

Follow these guidelines when air-sealing older multi-family buildings.

- ✔ Don't rely on blower door testing. You may get false readings from air that enters through the other dwelling units.
- ✔ Focus on sealing large air leaks and bypasses that are found by visual inspection. Enter the attic space and seal openings with rigid barriers, foam sealant, and caulk.
- ✔ Perform moisture control measures to protect insulation. Don't install insulation if both bulk water and airborne moisture can't be controlled.
- ✔ Install loose-fill insulation in attics, and densepack insulation in walls and "mystery cavities."

Attic ventilation is often unnecessary and ineffective in large multi-family buildings, and can increase heat loss and condensation especially if large air leaks are left unsealed.

5.3 INSULATION GUIDELINES

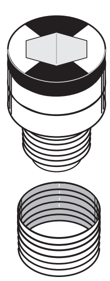
Insulation reduces heat transmission by slowing conduction, convection, and radiation through the building shell. Insulation combined with an air barrier forms the thermal boundary.

Installing insulation is one of the most effective energy-saving measures. Follow these general guidelines.

- ✔ Protect insulation from air movement with an effective air barrier. Make sure that the air barrier and insulation will be aligned using procedures outlined in *Section 5.2.*
- ✔ Protect insulation from moisture by repairing roof and siding leaks, and by controlling vapor sources within the home.
- ✔ Install insulation blankets so they cover the entire area without voids or edge gaps.
- ✔ Install loose-fill insulation at sufficient density to resist settling. Perform a bag count to achieve the density specified on the label of each bag.
- ✔ Fill wall cavities with densepack insulation. Perform a bag count to achieve 3.5 to 4.5 pounds per cubic foot. Fill cavities completely.
- ✔ Observe lead-safe weatherization practices with all tasks that may disturb interior paint. *See section 1.1.*

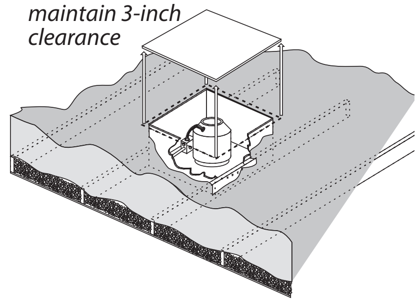
INSULATION SAFETY PROCEDURES

Comply with the following fire and electrical safety procedures before insulating.



S-type fuse: An S-type fuse prohibits residents from oversizing the fuse and overloading an electrical circuit.

- ✔ Inspect wiring, fuses, and circuit breakers to ensure that wiring isn't overloaded. Install S-type fuses where appropriate to prevent circuit overloading. Maximum ampacity for 14-gauge wire is 15 amps and for 12-gauge wire is 20 amps. Do not cover knob-and-tube wiring with insulation.
- ✔ Protect heat-producing fixtures such as recessed lights and exhaust fans with lights or heaters. Install an airtight box if air leakage is suspected, or a metal collar if they are airtight.



Recessed light fixtures: Covering recessed light fixtures with fire-resistant drywall or sheet-metal enclosures reduces air leakage and allows installers to safely insulate around the box.

- ✔ Confirm that all wire splices are enclosed in electrical junction boxes. If you plan to cover a junction box with insulation, mark its location with a sign or flag.
- ✔ Install insulation shields around unlined masonry chimneys, B-vent chimneys, and manufactured chimneys. Seal any bypasses around chimneys with metal and high-temperature caulk.
- ✔ Install insulation shields around all-fuel wood-stove chimneys with 6" of space between the chimney and insulation.
- ✔ If shields are used as a barrier around heating producing devices or masonry chimneys, fasten them securely to the ceiling joist so they maintain 3 inches of clearance and don't collapse. Don't allow metal shields to contact wiring. Cover the tops of

shields while installing insulation, and uncover and clean them out afterwards.

✔ Wear an approved respirators or dust mask while blowing insulation or installing batts. *See section 1.2.*

KNOB AND TUBE WIRING

When insulating around knob and tube wiring, use care to avoid creating a fire hazard. The following three methods have been used to protect knob and tube wiring; be sure to check with code authorities before determining which method is appropriate.

- When using batt insulation, free air circulation can be maintained by installing batt type insulation, unfaced or with the facing downward, to fill the joist under the wiring.
- When loose-fill type insulation is used, it should be tapered back from the edges of the batt so that loose-fill materials do not drift into contact with the wiring.
- Baffling around the knob and tube wiring can also be used. Acceptable materials shall provide minimum 3-inch air space, have flame spread 25 when tested in accordance with ASTM E-84-80, and be electrically non-conductive.

Installers may also follow this procedure which complies with the provisions of Section 324-4 of the National Electrical Code:

- The wiring shall be surveyed by an appropriately licensed electrical contractor who shall certify that the wiring is in good condition with no evidence of improper overcurrent protection, conductor insulation failure or deterioration, and with no improper connections or splices.
- Repairs, alterations or extensions of or to the electrical system shall be inspected by an electrical inspector.
- A copy of a Knob-and-Tube Inspection Certificate shall be placed in the client's file, and posted near the fuse or breaker box.

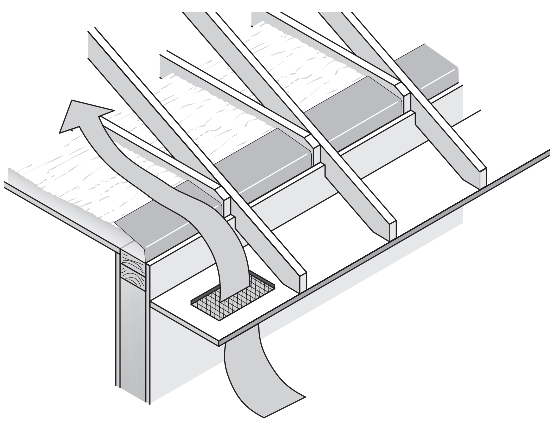
The insulation shall meet Class I specifications as identified in the Uniform Building Code, with a flame spread factor of twenty-five or less as tested using ASTM E84-81a. Foam insulation shall not be used with knob-and-tube wiring.

All knob-and-tube circuits shall have overcurrent protection in compliance with the National Electrical Code. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than the ampacity of the wire.

5.4 Attic Insulation

Perform these preparatory steps before installing attic insulation.

- ✔ Before insulating the attic, seal air leaks and bypasses as described previously. Air leakage and convection can significantly degrade the thermal resistance of attic insulation. If attic air leaks are not properly sealed, increasing attic ventilation may increase the home's air-leakage rate.
- ✔ Repair roof leaks and other attic-related moisture problems before insulating attic. If attic-related moisture problems can't be repaired, don't insulate the attic.
- ✔ Vent all kitchen and bath fans outdoors through roof or soffit fittings. Use PVC or rigid metal piping whenever possible, and insulate the pipe to prevent condensation. Avoid using flexible plastic ducting. Check all fans for proper backdraft damper operation. Repair or replace the damper or the entire fan assembly if the damper doesn't operate freely.

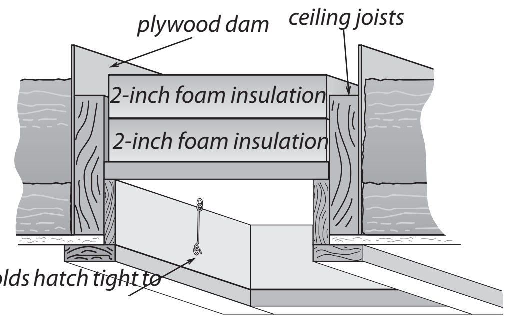


Soffit chute or dam: Allows installation of maximum amount of insulation in this cold area. Also prevents wind washing and airway blockage by blown insulation.

- ✔ Install chutes, dams, tubes, or other blocking materials to prevent blown insulation from plugging air channels between soffit vents and the attic. When correctly installed, these shields maximize the amount of insulation that may be installed over top plates without clogging ventilation paths. They also help prevent the wind-washing of insulation caused by cold air entering soffit vents.

Cardboard insulation baffles: Install the baffle so as to allow insulation to extend completely over the wall's top plate. Aligning the bottom edge of the baffle's side flanges with the bottom edge of the rafters will ensure an even air gap between the baffle and the underside of the roof sheeting.

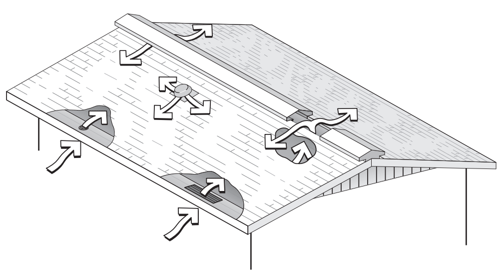
- ✔ Install an attic access hatch if none is present, preferably at the exterior of the home. The attic hatch should be at least 22 inches on each side if possible.
- ✔ Build an insulation dam around the attic access hatch. Build the dam with rigid materials like plywood or oriented-strand board so that it will support the weight of a person entering or leaving the attic. Insulate the hatch to an R-value that matches the attic insulation.



Insulated attic hatch: Foam insulation prevents this area from being a thermal weakness. Building a dam prevents loose-fill insulation from falling down the hatchway.

Attic ventilation

Attic ventilation is intended to remove moisture from the attic during the heating season and/or to remove solar heat from the attic during the cooling season. It is often ineffective, however, and adding attic ventilation during weatherization is seldom necessary.



Low and high attic ventilation: A moderate amount of ventilation creates air exchange with outdoors to remove moisture and to keep the attic from overheating in summer.

Many building codes require a minimum ratio of one square foot of net free area to 150 square feet of attic area if a vapor barrier isn't present. With a vapor barrier, only one square foot per 300 square feet of attic area is required.

It doesn't often work to add attic ventilation to cure a moisture problem caused by airborne moisture migrating up from the living space. Preventing moisture from entering the attic in the first place is the best way to keep attic insulation dry. Ceilings should be thoroughly air-sealed to prevent moist indoor air from leaking through the ceiling.

Excess attic ventilation can actually increase ceiling air leakage by increasing the stack effect. In some climates, nighttime cooling of the roof deck can also cause water vapor that enters on ventilation air to condense on attic surfaces.

CALCULATING ATTIC INSULATION COVERAGE

Loose-fill attic insulation should be installed to a uniform depth to attain proper coverage (bags per square foot) so it attains the desired R-value at the settled thickness. Attic insulation always settles: cellulose usually settles 10% to 20% and fiberglass settles 3% to 10%. Loose-fill wall insulation should be installed tightly enough that it cannot settle at all.

30 FT X 50 FT= 1500 SQ FT

Width — Length — Area of Attic

Step 1: Calculate area of attic:
Multiple length times width of the attic to get the area of attic.

1500 SQ FT ÷ 18.2 = 83 BAGS

Net wall Area — Sq. Ft. Coverage per Bag (from chart) — Estimated Bag Count

STEP 2: Calculate Bag Count:
Divide area of attic by coverage per bag from the chart on the bag (number circled in chart) to get your Estimated Bag Count. This example calls for an insulation value of R-30.

Table 5.4.1: Insulation blowing coverage chart

Example bag table

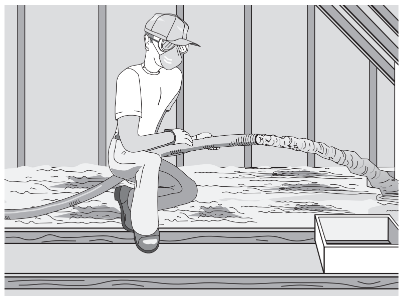
To obtain a minimum density of 1.6 pounds/cubic foot

	R VALUE AT 78° MEAN TEMP.	MINIMUM THICKNESS	MAXIMUM NET COVERAGE		MAXIMUM GROSS COVERAGE BASED ON 2" x 6" FRAMING		MINIMUM WEIGHTS PER SQ. FT.
	TO OBTAIN THIS R-VALUE	INSULATION SHOULD NOT BE LESS THAN THIS THICK	MAXIMUM SQ. FT. COVERAGE PER BAG	BAGS PER 1000 SQ. FT	MAXIMUM SQ. FT. COVERAGE PER BAG	BAGS PER 1000 SQ. FT.	THE WEIGHT PER SQ. FT. OF INSTALLED INSULATION (IN LBS.) SHOULD NOT BE LESS THAN
ATTIC	R-40	10.95	12.9	77.5	13.5	74.2	1.46
	R-38	10.41	13.6	73.5	14.2	70.3	1.38
	R-32	8.76	16.1	62.0	17.1	58.7	1.16
	R-30	8.21	17.2	58.0	18.2	54.8	1.09
	R-27	7.40	18.3	52.2	19.4	51.4	.98
	R-24	6.57	21.5	46.5	23.2	43.0	.87
	R-23	6.30	22.4	44.5	24.2	41.2	.84
	R-19	5.20	27.2	36.7	30.0	33.4	.69
	R-13	3.56	40.2	24.9	46.0	21.7	.47
	R-11	3.01	47.1	21.2	56.0	17.8	.40
SIDEWALLS					2X4 STUDS ON 16" O.C.		
	R-13	3.5			23.6	42.40	.79
	R-19	5.5			15.0	66.60	

BLOWING ATTIC INSULATION

Install attic insulation to a cost effective R-value, depending upon existing insulation level and climatic region.

Blown insulation is preferred to batt insulation because blown insulation forms a seamless blanket.



Blown-in attic insulation: Blown insulation is more continuous than batts and produces better coverage. Insulation should be blown at a high density to reduce settling.

Blowing attic insulation at the highest achievable insulation density helps minimize settling and slows convection currents from moving within the insulation.

Follow these standards when installing loose-fill attic insulation.

- ✔ Perform a bag count to determine how much insulation is needed to achieve the density specified on the bag's label.
- ✔ Maintain a high density by moving as much insulation as possible through the hose with the available air pressure. The more the insulation is packed together in the blowing hose, the greater its density will be.
- ✔ Fill the edges of the attic first, near the eaves or gable end, and move toward the center. Don't leave thin places over the wall plates.
- ✔ Install insulation at an even depth. Go back and use a stick to level the insulation if needed.
- ✔ Post an Insulation Certificate near the attic entrance.

INSTALLING ATTIC BATT INSULATION

Follow these standards when installing fiberglass batts in the attic.

- ✔ Install unfaced fiberglass insulation whenever possible. Faced insulation doesn't tend to lay as flat as un-faced batts, and the facing is not effective in slowing vapor movement anyway.
- ✔ If you must install faced batts, install it with the facing toward the heated space. Never install faced insulation over existing insulation.
- ✔ Cut batts carefully to ensure a tight fit against the ceiling joists and other framing.

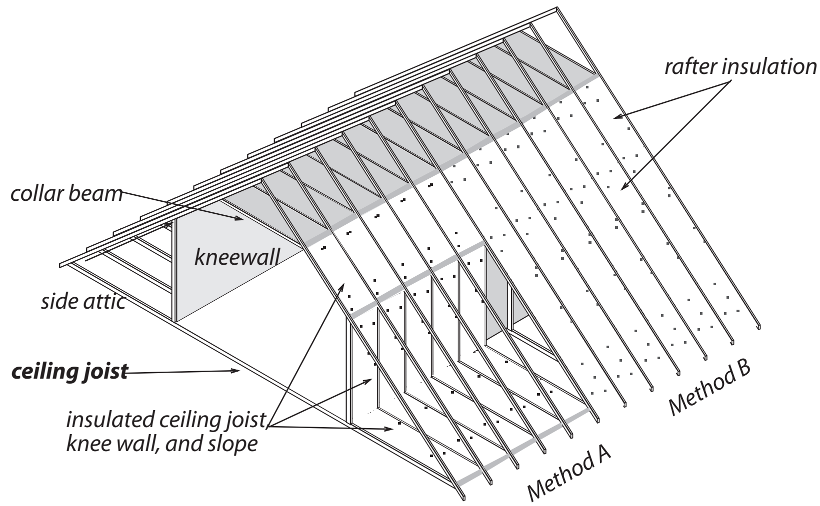
FINISHED KNEE WALL ATTICS

Finished attics require special care when installing insulation. They often include five separate sections that require different sealing and insulating methods.

- Exterior walls of finished attic
- Collar-beam attic, above finished attic
- Sloped roof, where wall/roof finish is installed directly to roof rafters
- Knee walls, between finished attic and unconditioned attic space
- Outer ceiling joists, between knee wall and top plate of exterior wall

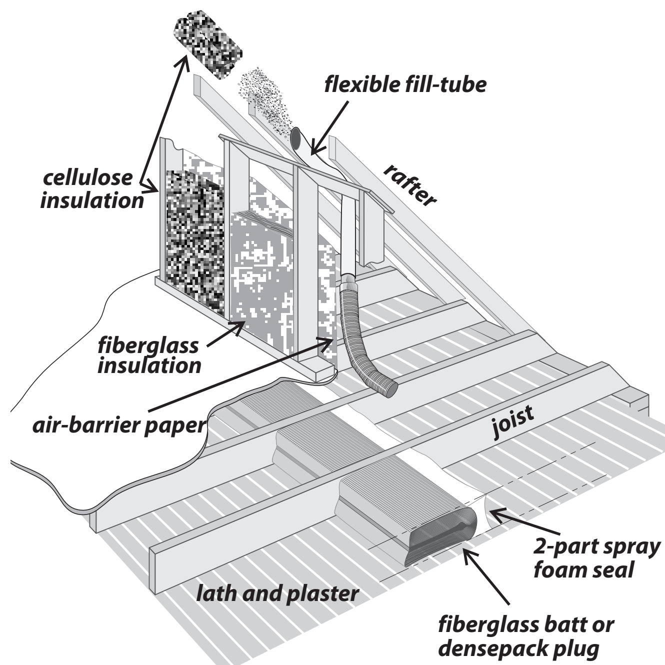
Follow these specifications when insulating finished attics.

- ✔ Seal large air leaks when they are adjacent to the conditioned space. Some small cavities can be sealed with densepack insulation.
- ✔ Inspect the structure to confirm that it has the strength to support the weight of the insulation.



Finished attic: This illustration depicts two approaches to insulating a finished attic. Either A) insulate the kneewall and side attic floor, or B) insulate the rafters.

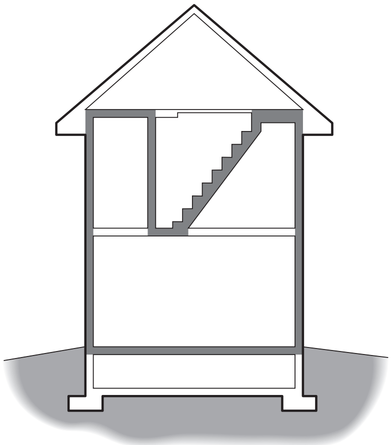
- ✔ Create an airtight and structurally strong seal in the joist space under the knee wall. This can be done by either blowing densepack cellulose into the joist cavities, by inserting 2-inch-thick foam sheets and foaming their perimeters with one-part foam, or by inserting a fiberglass batt into the cavity and foaming its face with two-part spray foam.
- ✔ Insulate sloped roof with densepack cellulose.
- ✔ Insulate knee walls with densepack cellulose or fiberglass batts. Prepare the knee wall for blowing by nailing house wrap to the knee wall with large-headed nails or stapling the house wrap through a strip of cardboard or thin wood. Or insulate the knee wall with high-density batts and apply house wrap to the attic side of the wall to prevent convection and air leakage.
- ✔ When the knee wall area is used for storage, cover insulation with a vapor-permeable material such as house wrap to prevent exposure to insulation fibers.
- ✔ Insulate knee wall access hatches and collar-beam access hatch with 3 or more inches of rigid-foam insulation, or a well-secured fiberglass batt. Weatherstrip the hatch and provide a positive closure.



Finished attic best practices: Air sealing and insulation combine to dramatically reduce heat transmission and air leakage in homes with finished attics.

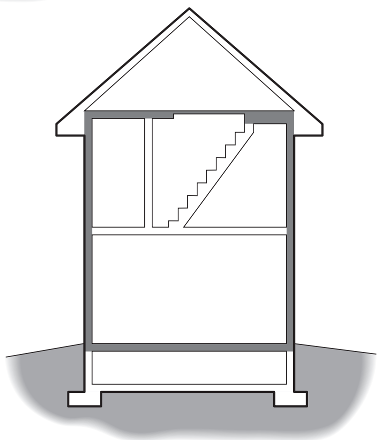
Walk-up Stairways and Doors

Think carefully about how to establish a continuous insulation and air barrier around or over the top of an attic stairway. If the attic is accessed by a stairwell and standard vertical door, you can blow dense pack cellulose insulation into walls of the stairwell. Install a threshold or door sweep, and weatherstrip the door. Also blow packed cellulose insulation into the cavity beneath the stair treads and risers.



Insulating and sealing attic stair walls, doors, and stairs: Insulating and air sealing these is one way of establishing the thermal boundary.

Insulating and weatherstripping the attic hatch: Air sealing around the hatch is an alternative way of establishing the thermal boundary.

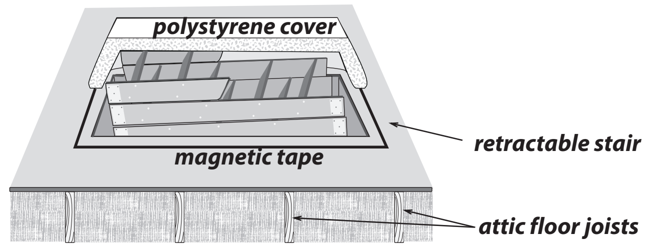


You can also establish the thermal boundary at the ceiling level, but this requires a horizontal hatch at the top of the stairs.

When planning to insulate stairwells, investigate barriers such as fire blocking that might prevent insulation from filling cavities you want to fill, and consider what passageways may lead to other areas you don't want to fill such as closets. Balloon-framed walls and deep stair cavities complicate this measure.

Insulating & sealing retractable attic stairways

Retractable attic stairways are sometimes installed above the access hatch. Building an insulated box or buying a manufactured stair-and-hatchway cover are good solutions to insulating and sealing this weak point in the thermal boundary.



Manufactured retractable-stair cover: Magnetic tape forms the seal of this manufactured molded polystyrene insulated cover.

5.5 WALL INSULATION

If you find the existing walls uninsulated or partially insulated, add insulation to provide complete coverage for all the home's exterior walls.

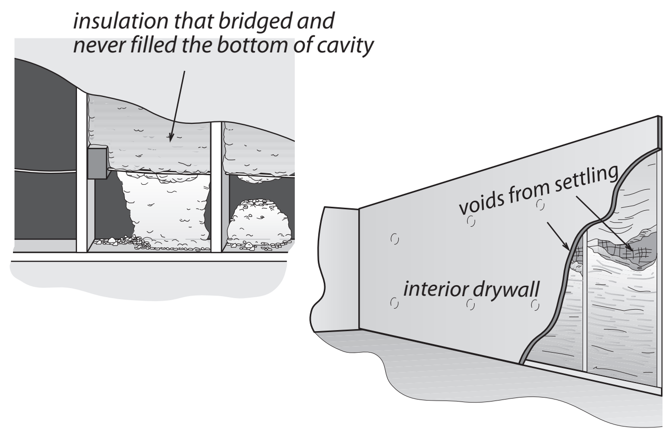
Properly installed cellulose wall insulation reduces air leakage through walls and other closed building cavities because the fibers are driven into the cracks by the blowing machine.

Install wall insulation with a uniform coverage and density. Wall cavities encourage airflow like chimneys. Convection currents or air leakage can significantly reduce wall insulation's thermal performance if spaces remain for air to flow.

Two methods for installing sidewall insulation are commonly used: tube-fill method (one large hole) or the two-hole method. The tube-fill method is preferred because it ensures that wall achieves an adequate coverage and density of insulation.

INSPECTING AND REPAIRING WALLS

- ✔ Inspect walls for evidence of moisture damage. If condition of the siding, sheathing, or interior wall finish indicates an existing moisture problem, no sidewall insulation should be installed until the moisture problem has been identified and corrected.
- ✔ Seal gaps in external window trim and other areas that may admit rain water into the wall.
- ✔ Inspect indoor surfaces of exterior walls to assure that they are strong enough to withstand the force of insulation blowing. Add screws or other reinforcement to weak walls if feasible.
- ✔ Inspect for interior openings from which insulation may escape such as balloon framing openings in the attic or crawl space, pocket doors, un-backed cabinets, interior soffits, and closets. Seal openings as necessary to prevent insulation from escaping.
- ✔ Confirm that exterior wall cavities aren't used as return ducts. Avoid these cavities, or re-route the ducting.
- ✔ Ensure that electrical circuits contained within walls aren't overloaded. Maximum ampacity for 14-gauge copper wire is 15 amps and for 12-gauge copper wire is 20 amps. Install S-type fuses where appropriate to prevent circuit overloading.



Problems with low density insulation: Blowing insulation through one or two small holes usually creates voids inside the wall cavity. This is because insulation won't reliably blow at an adequate density more than about one foot from the nozzle.

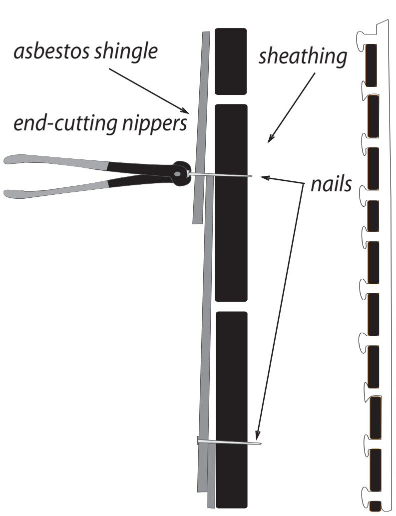
Use tube-filling methods whenever possible, using a 1 1/2″ hose inserted through a 2″ or larger hole.

REMOVING SIDING AND DRILLING SHEATHING

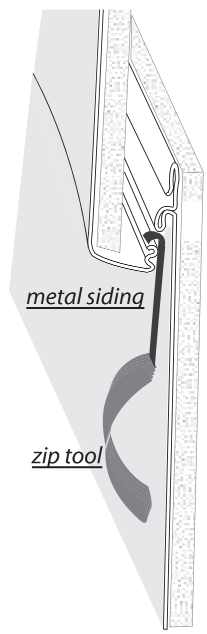
Avoid drilling through siding. Where possible, carefully remove siding and drill through sheathing. This avoids the potential lead-paint hazard of drilling the siding. It also makes it easier to insert flexible fill tubes since the holes pass through one less layer of material.

If the siding cannot be removed, consider drilling the walls from inside the home. Obtain the owner's permission before doing so, and practice lead-safe weatherization procedures.

- ✔ Asbestos shingles may be carefully removed by pulling the nails holding them to the sheathing or else nipping off the nailheads. Dampening the asbestos tiles keeps dust down. Refer to your company standards for proper protective equipment when working with asbestos materials.
- ✔ Metal or vinyl siding may be removed with a zip tool.
- ✔ Homes with brick veneer or blind-nailed asbestos siding may be insulated from the inside. Holes drilled for insulation must be returned to an appearance as close to original as possible, or so they are satisfactory to the customer.



Removing asbestos shingles: End-cutting nippers are used to pull the two face nails out of each shingle. Holes are then drilled in the sheathing for tube filling.

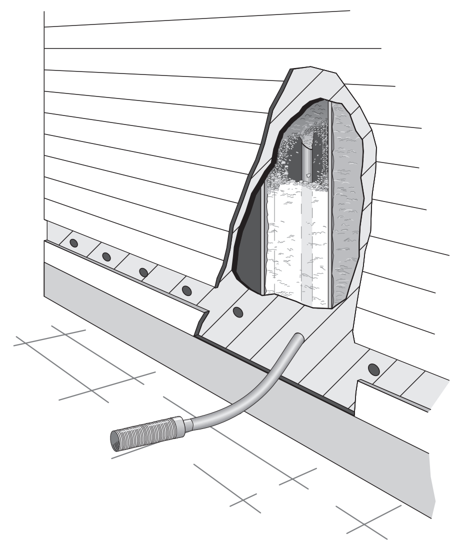


Removing metal siding: A zip tool separates joints in metal siding.

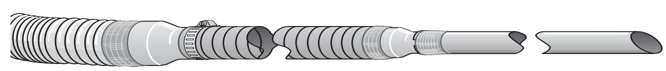
Dense-pack method

Dense-pack wall insulation is best installed using a powerful blower equipped with separate controls for air and material feed. Tuning and adjusting the machine is critical to maintaining performance. Check your blowing pressure periodically to confirm that the machine can achieve the required density.

To prevent settling, cellulose insulation must be blown at 3.5-4.5 pounds per cubic foot density. This minimum density translates into 1.2 pounds per square foot in a 2-by-4 wall cavity on 16-inch centers, and 1.8 pounds per square foot in a 2-by-6 wall cavity on 16-inch centers. Blowing cellulose insulation this densely typically requires using a fill tube.



Tube-filling walls: This method can be accomplished from inside or outside the home. It is the preferred wall insulation method because it is a reliable way to achieve a uniform coverage and density.



Insulation hoses, fittings, and the fill tube: Smooth, gradual transitions are important to the free flow of insulation.

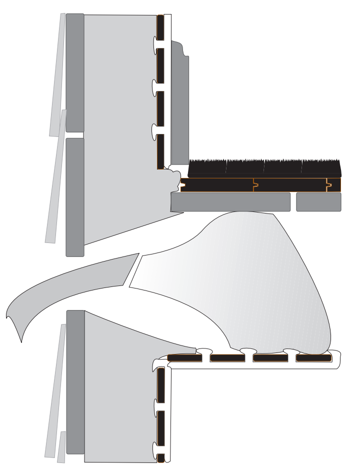
Insulate walls by this procedure.

1. Mark the fill tube in one-foot intervals to help the installer verify when the tube has reached the top of the wall cavity.
2. Drill 2-to-3-inch diameter holes to access stud cavity.
3. Probe all wall cavities through holes, as you drill them, to identify fire blocking, diagonal bracing, and other obstacles. After

probing, drill whatever additional holes are necessary to ensure complete coverage.

4. Start with several full-height, unobstructed wall cavities so you can measure the insulation density and calibrate the blower. An 8-foot cavity (2-by-4 on 16-inch centers) should consume a minimum of 10 pounds of cellulose.
5. Insert the hose all the way to the top of the cavity. Start the machine, and back the hose out slowly as the cavity fills. Work the hose back and forth in the cavity to pack the insulation tighter.
6. Shut off the flow of material when about 6" from the end.
7. Seal and plug the holes, and replace the siding.

When insulating balloon-framed walls, try to blow an insulation plug into each floor cavity to insulate the perimeter between the two floors. This also seals the floor cavity so it does not become a conduit for air migration.



Sealing the floor cavity: Dense pack insulation can effectively seal this hard-to-reach cavity. If the process is requiring too much insulation, try placing a plastic bag over the end of the fill tube and blowing the insulation into the plastic bag.

Two-hole method

The two-hole method is often used when the insulator doesn't want to remove siding. The two-hole method is the least preferable wall-insulation method because it often results in voids and substandard density. It is sometimes used effectively in conjunction with tube-filling to fill small cavities around doors or windows.

If you do employ this method, use a powerful blowing machine, preferably one with a gasoline engine.

- ✔ Drill two holes into each stud cavity large enough to admit a directional nozzle. The top hole should be located no more than 20 inches below the top plate. The bottom hole should be no more than 24 inches above the bottom plate.
- ✔ Probe wall cavities to determine location of obstacles and nature of cavities around window and door areas.
- ✔ All wall cavities around windows and doors should be filled with insulation.
- ✔ Seal all holes with wood or plastic plugs.

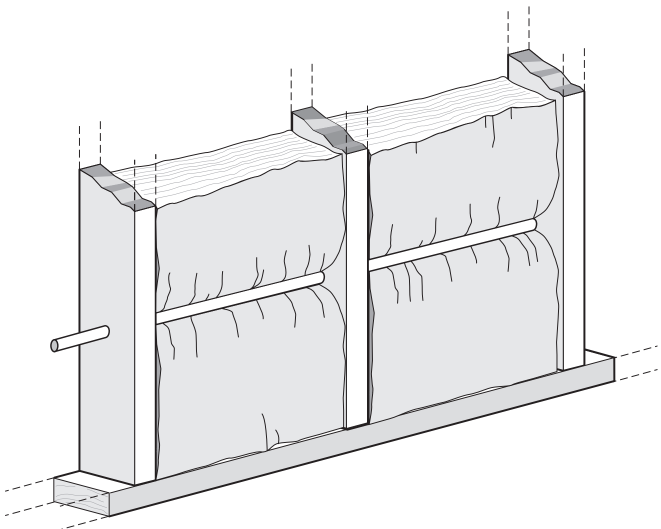
Open-cavity wall insulation

Fiberglass batts are the most common open-cavity wall insulation. They achieve their rated R-value only when installed carefully. If there are gaps between the cavity and batt at the top and bottom, the R-value can be reduced by as much as 30 percent. The batt should fill the entire cavity without spaces in corners or edges.

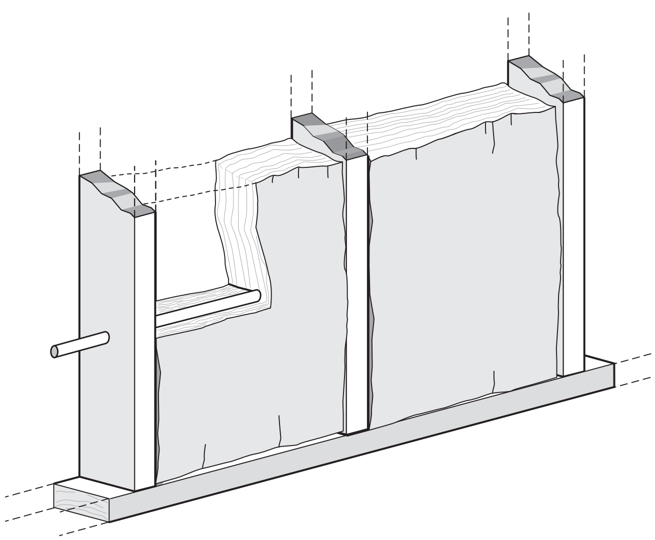
- ✔ Use unfaced friction-fit batt insulation where possible. Fluff to fill entire wall cavity.
- ✔ Choose medium density (R-13) or high density (R-15) batts rather than R-11.
- ✔ Staple faced insulation to outside face of studs on the warm side of the cavity. Do not staple on the side of the studs.
- ✔ Cut batt insulation to the exact length of the cavity. A too-short batt creates air spaces above and beneath the batt, allowing convection. A too-long batt will bunch up, creating air pockets.
- ✔ Split batt around wiring, rather than letting the wiring bunch the batt to one side of the cavity.

✔ Insulate behind and around obstacles with scrap pieces of batt before installing batt.

Fiberglass insulation exposed to the interior living space must be covered with minimum half-inch drywall or other material that has an ASTM flame spread rating of 25 or less. Fiberglass insulation with a fire-resistant foil-scrim-kraft (FSK) facing does not require an additional fire barrier.



Fiberglass batts, compressed by a cable: This reduces the wall's R-value by creating a void between the insulation and interior wallboard.



Batt, split around a cable: The batt attains its rated R-value.

CALCULATING WALL INSULATION COVERAGE

You can estimate the bag count for wall insulation jobs by this method.

(2 X 50 FT) + (2 X 30 FT) = 160 FT

Length | Width | Perimeter of House

STEP 1: Calculate perimeter of house:
Calculate the perimeter of the house. If the house is a simple rectangle or near a simple rectangle, use the formula above. If the house has numerous unequal sides, simply add the lengths together to find the perimeter.

160 FT X 8 FT= 1280 SQ FT

Perimeter of House | Height of Wall | Total Wall Area

STEP 2: Calculate total wall area:
After calculating the perimeter of the house, multiply it times the wall height. This will give you the total wall area.

1280 SQ FT - 150 SQ FT= 1130 SQ FT

Net Wall Area | Area of Windows and Doors | Net Wall Area

STEP 3: Calculate Net Wall Area:
Calculate the sum of the areas of windows and doors. Subtract them from the total wall area to get net wall area.

1130 SQ FT ÷ 23.6 = 47.9 BAGS

Net Wall Area | Sq. Ft. Coverage per Bag (from chart) | Estimated Bag Count

STEP 4: Calculate Bag Count:
Divide net wall area by coverage per bag from the chart on the bag (number circled in sample chart) to get your estimated bag count.

5.6 Floor and Foundation Insulation

Floor and foundation insulation are undertaken in conjunction with air sealing to complete the thermal boundary at the base of the building.

In homes with heated and occupied basements, the best choice is to insulate and air-seal the basement walls, and so include the basement within the thermal boundary. The choice is less straightforward in homes with unused basements or crawl spaces where a choice must be made between insulating the floor or the foundation walls. This decision should be made according to cost-effectiveness.

Establishing a Thermal Boundary

To establish an effective thermal boundary, the insulation and air barrier should be adjacent to each other. Establishing an effective air barrier—comparable to the air barriers in the above-grade walls and ceiling—may be difficult. Furthermore, foundation or floor insulation may or may not be cost-effective or practical, considering the home's weatherization budget and potential moisture problems.

Most building experts prefer to insulate and air-seal the foundation walls and not the floor because this strategy encloses the furnace, ducts, pipes and other features within an insulated and air-sealed space. This involves plugging crawl-space vents if appropriate.

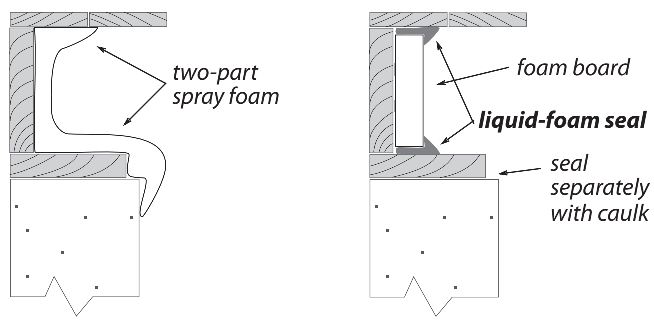
Floor insulation is generally preferred where there are crawl-space moisture problems or where rubble masonry makes insulating and air-sealing the foundation wall difficult.

Rim Insulation and Air Sealing

The joist spaces at the perimeter of the floor are a major weak point in the air barrier and insulation. Insulating and air sealing both the rim joist and longitudinal box joist are appropriate either as individual procedures or as part of floor or foundation insulation.

Air-seal stud cavities in balloon-framed homes as a part of insulating the rim joist. Air-seal other penetrations through the rim before insulating. Two-part spray foam is the most versatile air-sealing and insulation system for the rim joist because spray foam air-seals and insulates in one step. Polystyrene or polyurethane rigid board insulation is also good for insulating and air-sealing the rim joist area. Longitudinal box joist cavities, enclosed by a floor joist, may be sealed and blown with wall insulation unless moisture is present.

Fiberglass-batt insulation should not be used because air can circulate around the fiberglass causing condensation and encouraging mold on the cold rim joist. If foam-board is used to insulate the rim, liquid foam sealant should be used to seal around the edges.



Foam-insulated rim joists: Installing foam insulation is the best way to insulate and air-seal the rim joist.

Floor Insulation

All appropriate measures should be taken to establish an effective air barrier at the floor, prior to insulating the floor, to prevent air from passing through or around floor insulation.

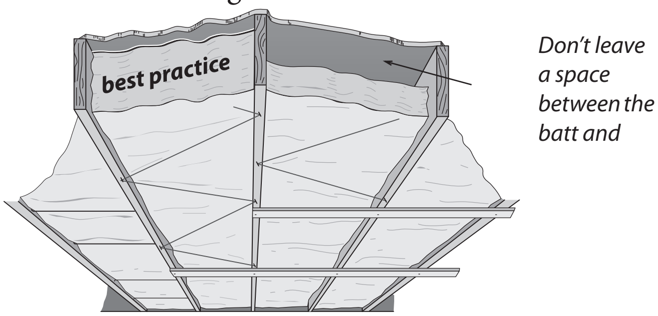
The best way to insulate a floor cavity is to completely fill the joist cavity with unfaced fiberglass batt insulation. Partially filling the cavity with a fiberglass batt is less satisfactory because air movement above the batts reduces their effectiveness.

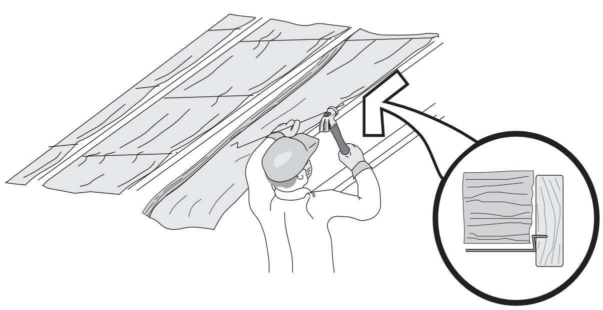
✔ If the walls are balloon-framed, air-seal the bottoms of the stud cavities prior to installing floor insulation to contain wall insulation.

✔ Install R-19 insulation between floor joists.

✔ Fit floor insulation tightly against the subfloor and the rim joist to reduce air convection.

✔ Install insulation without voids, edge gaps, or end gaps. Fit insulation closely around cross bracing and other obstructions.





Floor insulating with batts: Use unfaced fiberglass batts, installed flush to the floor bottom, to insulate floors. The batt should fill the whole cavity if it is supported by lath or plastic twine underneath. For batts that don't fill the whole cavity, use wire insulation supports.

✔ Securely fasten batt insulation to framing with insulation hangers, plastic mesh, or other supporting material.

✔ Insulate water lines if they protrude below the insulation.

✔ Seal and insulate ducts remaining in the crawl space or unoccupied basement.

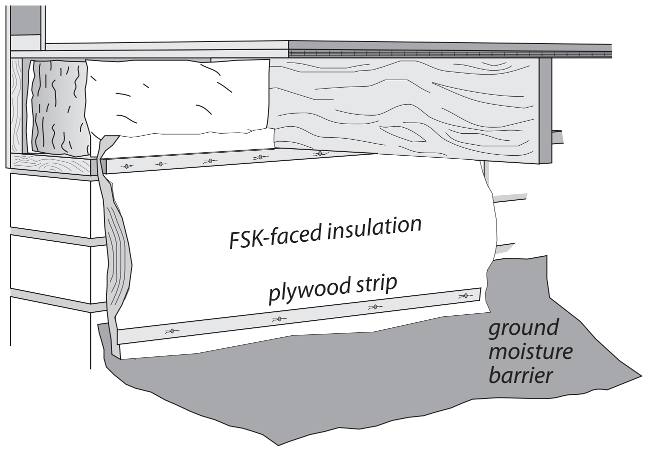
✔ Install a ground moisture barrier that runs up the foundation walls in crawl spaces. Secure the ground moisture barrier to the foundation wall with urethane sealant and/or mechanical fasteners.

Foundation insulation

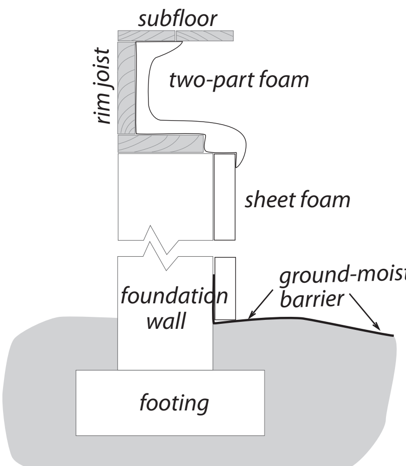
Foundation insulation is usually installed the inside of the foundation wall during retrofits. Exterior insulation is common in new construction because it is more effective at slowing ground water migration through the foundation.

Extruded or expanded polystyrene insulations are the most appropriate insulation products for flat concrete or concrete-block walls, because they are good air barriers with excellent moisture resistance. For rubble masonry walls, use two-part spray foam. Spray foam is preferred whenever there is much moisture present.

- Attach insulation firmly to the entire inside wall surface with appropriate fasteners and/or adhesive. Install insulation with no significant voids or edge gaps. Fiberglass insulation can be cut to fit the rim joist area.
- Cover basement foundation insulation with a material that has an ASTM flame spread rating of 25 or less, such as half-inch drywall. FSK fiberglass needs no additional barrier.

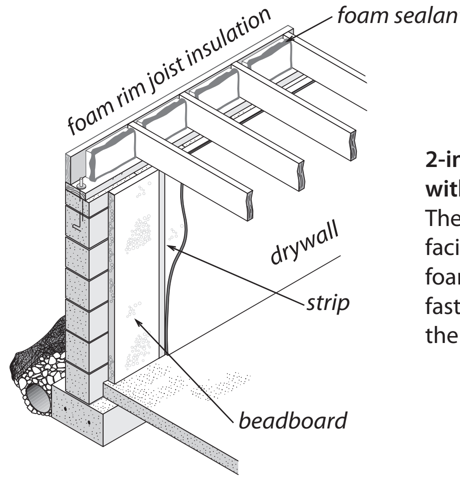


Fiberglass crawl-space insulation: An FSK-faced fiberglass blanket can be used to insulate a crawl space. Every crawl space should have a ground moisture barrier.

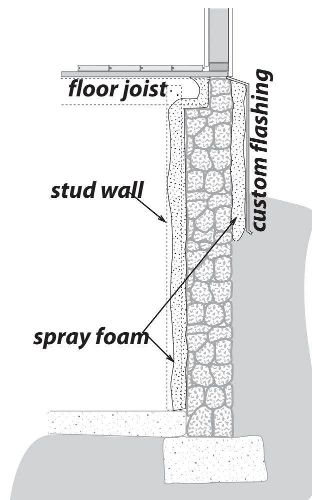


Foam-insulated crawl space: Two-part foam insulates and seals the rim joist and sheet foam insulates the foundation walls.

- FSK (foil scrim kraft) fiberglass insulation should be clamped to the sill plate by a wooden strip, which is nailed, stapled, or screwed into the sill. The bottom of this batt insulation should be air-sealed to the wall with a strip of wood nailed into the foundation or by sealing the FSK facing to the wall with caulk, or by any other effective method. Stop the insulation short of the sill plate in areas where termites are common because it can provide a hidden pathway for their entrance into the building.
- If the heating system is located in crawl space, take precautions to assure that adequate outside combustion air is available.
- Outside access hatches should be securely attached to foundation wall. If the foundation walls are insulated, any crawl-space access hatch into a conditioned basement should be insulated.



2-inch foam board with plywood strips: The built-in strips facilitate fastening the foam to the wall and fastening drywall to the foam.



2-part foam sprayed on rubble masonry: Rubble masonry walls can be insulated on the interior or exterior with sprayed plastic foam. On the interior, the foam must be covered by drywall.

Crawl space ventilation

Crawl-space ventilation is generally not effective at controlling moisture migration, and it defeats the thermal barrier if foundation insulation is installed. Rely instead on these other source control measures.

- ✔ Extend any ducts from exhaust fans or clothes dryers to the outside. Use rigid piping whenever possible since flex duct tends to restrict airflow. If you must use short runs of flex duct, use only aluminum ducting and fasten it securely to avoid sags.

- ✔ Slope the ground outside the home away from the foundation.
- ✔ Install gutters and downspouts in very wet locations.
- ✔ Install a ground moisture barrier.

If you have effectively reduced moisture sources, seal the foundation vents if local codes allow. If crawl space ventilation is absolutely required by local codes, install one square foot of net free ventilation area for every 1500 square feet of crawl-space floor area. A minimum of two vents should be installed on opposite sides of the crawl space.

Ground moisture barriers

Air, moisture, and pollutants can move through soil and into crawl spaces and dirt-floor basements. Even soil that seems dry at the surface can release a lot of moisture into the home.

Cover the ground in these areas with an airtight barrier to control the movement of moisture and soil gases.

- ✔ Cover the ground completely with a ground moisture barrier such as black six-mil plastic or cross-laminated polyethylene.
- ✔ Run the barrier up the foundation wall several inches. Attach it to the mud sill only you know that termites aren't a problem in your area, and that moisture condensation isn't likely against the foundation wall.
- ✔ Seal the edges and seams with urethane adhesive to create an airtight seal.

5.7 WINDOWS AND DOORS

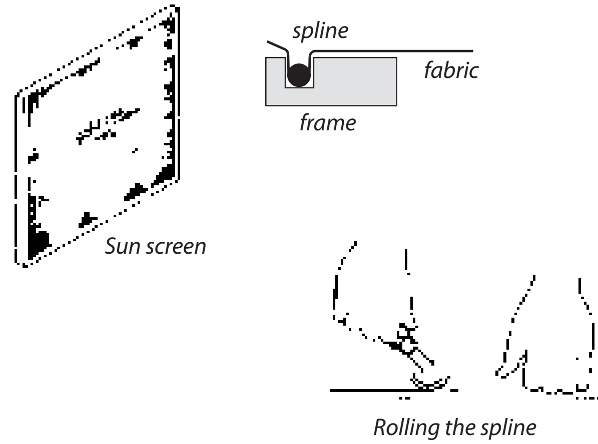
Windows and doors were once thought to be a major air-leakage problem. However, the wide-spread use of blower doors has shown that windows and doors don't tend to harbor large air leaks. Though conductive and convective losses through windows and doors are often quite high, these aren't affected much by most simple weatherization improvements.

If windows and doors are in poor condition, their repair is often essential for a building's survival even if it's not an energy-saving measure. Repairs that go beyond the cost-effective standards of the Weatherization Assistance Program should be limited to funds that are dedicated to repair work. All tasks relating to window and door repair should be accomplished using lead-safe weatherization methods.

SUN SCREENS

Sun screens, made of mesh fabric that is stretched over an aluminum frame, are one of the most effective window-shading options in hot climates. They absorb or reflect a large portion of the solar energy that strikes them, while allowing a slightly diminished but acceptable view out of the window.

Sun screens are installed on the outside of the window, and work well on fixed, double-hung, or sliding windows. They aren't suitable for jalousie windows. For casement and awning windows, the sun screen should be mounted on the movable window sash rather than on the window frame.



Sun screens: Installed on the window's exterior, sun screens absorb solar heat before it enters the home. This strategy is superior to interior window treatments, which reflect heat back after it has entered.

Sun screens are easily constructed in the shop or on the job.

- ✔ Cut the frames to size using a metal cutting saw.
- ✔ Fasten the frames together through reinforced corner pieces.
- ✔ Cut the fabric a few inches large in length and width, and stretch it into the frame using continuous soft plastic splines that fit into the frame.
- ✔ Cut the excess fabric from around the edges.

Install sun screens on the exterior of the window frame, trim, or sash. Drill pilot holes for screws that pass through the aluminum frame, or use clips that are screwed to the window frame outside the sun screen. Use aluminum fasteners on aluminum frames to avoid corrosion.

Other exterior window shades such as awnings, shutters, or rolling shades can provide good window shade, but are generally too expensive for weatherization programs.

Interior window shades

Interior shades or curtains are not as effective as exterior shades because they reflect solar energy back after it enters the home. Much of this heat is absorbed by the shade and remains in the home.

Opaque or room-darkening roller shades with bright white or metallic surfaces can block some solar heat. The reflective surface should face outdoors. The interior surface can be any color.

Venetian blinds, mini-blinds, or cellular pleated shades are more expensive and somewhat less effective than roller shades, although they may have better acceptance among occupants. Traditional fabric curtains are the least effective solar shade.

Avoid translucent or light-admitting shades because they allow more heat to enter the home. Purchase window shades in the standard sizes that fit most windows since custom-sized shades are considerably more expensive.

Good management of window shades improves their effectiveness. Discuss these principles with the clients.

- ✔ Close window shades in the morning before the home begins to heat up. Close the windows.
- ✔ Open shades in the evening to help cool the home. Open the windows.
- ✔ Open shades all day during winter to allow solar heat to enter the home.

Interior reflective window films, like those used on automobiles, provide shading while maintaining a view. They must be quite dark, however, to provide much cooling benefit, and they don't allow solar energy to enter the home in winter. Do not install reflective films on double-pane windows as they can cause overheating of the insulated glass unit that damages the edge seal.

Landscaping for shade

Trees and bushes can provide shade for windows, walls, and roofs. They also cool the air around the home with shade and moisture evaporating from their leaves. Well-planned landscaping can reduce an un-shaded home's air-conditioning costs by up to 50% while adding value to the home and neighborhood.

Trees for shade: Landscaping is a good long-term investment for residences. Tall deciduous trees on the south block high summer sun while allowing lower winter sun to reach the home. Shorter trees or bushes provide protection from low-angle sun on the east and west.

The best plan for cool landscaping includes tall deciduous trees on the south side of the home to block high mid-day sun. Shorter trees or bushes on the east and west block morning and afternoon sun.

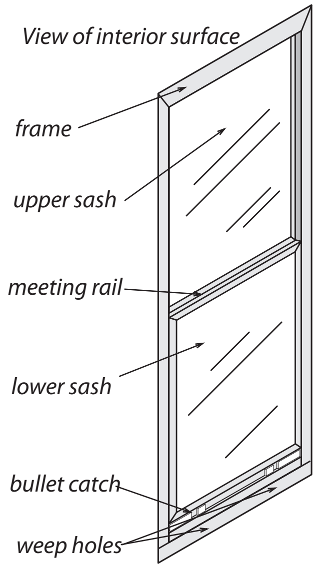
Plant deciduous trees that loose their leaves in the autumn to admit winter sun. Choose types that are quick-growing and easy to care for in your region. Check with a local nurseryman to determine the best type of trees, when to plant, and method of planting.

Exterior storm windows

Storm windows are relatively expensive when compared to other weatherization measures, and so are not always cost effective. Storm windows can preserve old worn primary windows, though, which can be cheaper than replacing the primary windows.

Aluminum storm window are the best choice if they are well designed and installed properly.

- Frames should have sturdy corners so they don't rack out-of-square during transport and installation.
- Sashes must fit tightly in their frames.
- The gasket sealing the glass should surround the glass's edge and not merely wedge the glass in place against the metal frame.
- The window should be sized correctly and fit tightly in the opening.



Aluminum exterior storm windows: They protect the primary window and add about an R-1 to the window assembly.

The installation of storm windows should follow these guidelines.

✔ Do not install new storm windows to replace existing storms if the existing storms are in good condition or can be repaired at a reasonable cost.

✔ Caulk storm windows around the frame at time of installation, except for weep holes that should not be sealed. If weep holes are not manufactured into new storm window, weep holes should be drilled into them.

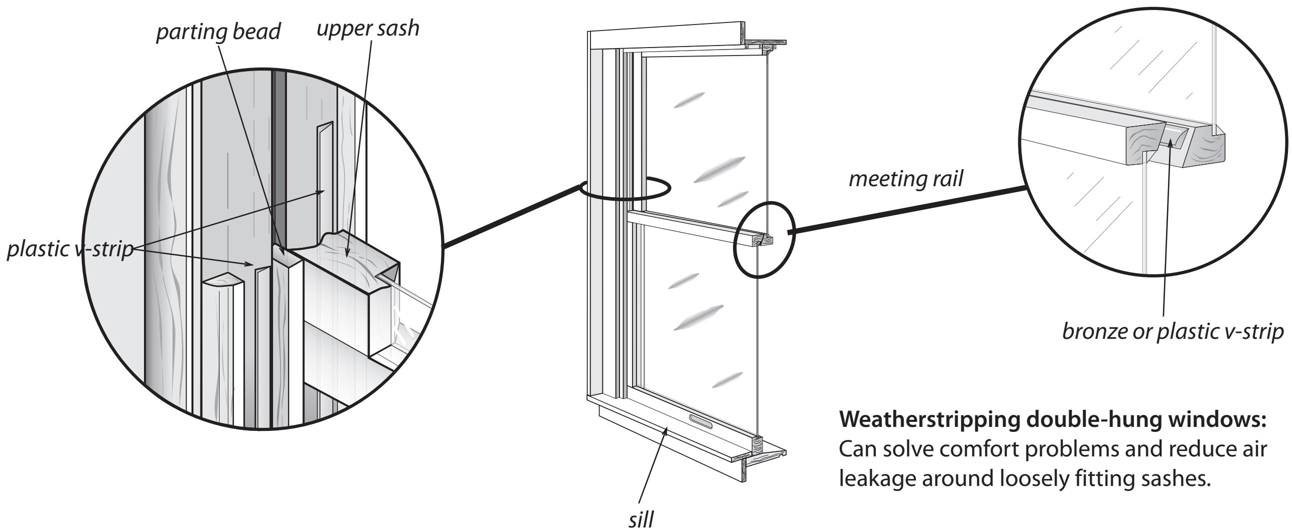
✔ Do not allow storm-windows to restrict emergency egress or ventilation through moveable windows. Choose windows that are openable from the inside, or install pin-on storm sashes that open along with the moveable primary window.

Window repair and air-leakage reduction

With the exception of broken glass or missing window panes, windows are rarely the major source of air leakage in a home.

Window weatherstripping is typically not cost-effective but may be installed to solve a comfort problem. Avoid expensive or time-consuming window-repair measures that are implemented to solve minor comfort complaints.

Re-glazing window sashes is time consuming, and is best accomplished as part of a comprehensive window rehabilitation project. Re-glazing wood windows may not be a durable repair without thorough scraping, priming, and painting. Repair measures may include the following measures.



Weatherstripping double-hung windows: Can solve comfort problems and reduce air leakage around loosely fitting sashes.

- ✔ Replace missing or broken glass. Use glazing compound and glazier points when replacing glass in older windows. Glass cracks that are not noticeably separated can be ignored.
- ✔ Caulk interior and exterior window frame to prevent air leakage, condensation, and rain leakage. Use sealants with rated adhesion and joint-movement characteristics appropriate for both the window frame and the building materials surrounding the window.
- ✔ Replace missing or severely deteriorated window frame components. Extremely damaged wood should filled with a marine epoxy, primed, and painted.
- ✔ Adjust window stops if large gaps exist between stop and jamb. Ensure that window operates smoothly following stop adjustment.
- ✔ Weatherstrip large gaps between the sash and the sill or stops. Weatherstrip the meeting rails if needed.
- ✔ Replace or repair missing or non-functional top and side sash locks, hinges or other hardware if such action will significantly reduce air leakage.

Use lead-safe weatherization practices when working on windows. *See section 1.1.*

Weatherstripping double-hung windows

Wooden double-hung windows are fairly easy to weatherstrip. Window weatherstripping is mainly a comfort retrofit and a low weatherization priority.

Paint is the primary obstacle when weatherstripping double-hung windows. Often the upper sash has slipped down, and is locked in place by layers of paint, producing a leaking gap between the meeting rails of the upper and lower sashes.

- ✔ To make the meeting rails meet again, either break the paint seal and push the upper sash up, or cut the bottom of the lower sash off to bring it down.
- ✔ To lift the upper sash, cut the paint around its inside and outside perimeter. Use leverage or a small hydraulic jack to lift the sash. Jack only at the corners of the sash. Lifting in the middle will likely break the window.
- ✔ Block, screw, or nail the repositioned upper sash into place.
- ✔ To weatherstrip the window, you must remove the lower sash. Cut the paint where the window stop meets the jamb so the paint doesn't pop off in large flakes as you pry the stop off. Removing one stop is sufficient to remove the bottom sash.
- ✔ Scrape excess paint from the sashes and the window sill. You may need to plane the sides so the window operates smoothly.
- ✔ Apply vinyl V-strip to the side jambs, and bronze V-strip to the meeting rail on the top sash. The point of the bronze V goes skyward. The weatherstrip is caulked on its back side and stapled in place, as shown in the illustration.

Window replacement

Window replacements are generally not cost-effective energy conservation measures. Replace windows only as emergency-repair measures when the window is missing, or damaged beyond repair, or found to be cost-effective.

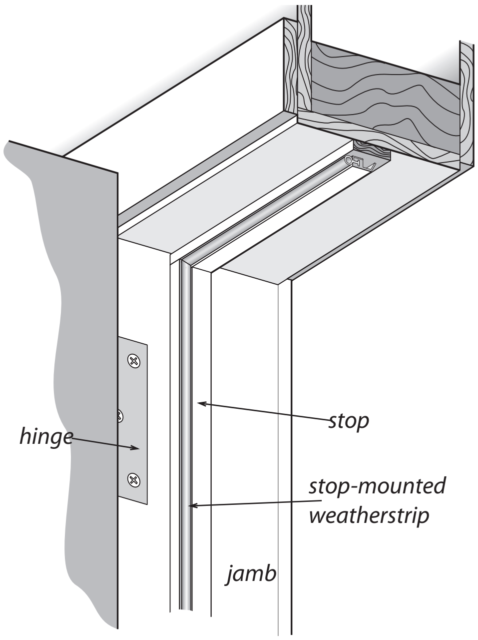
Replacement windows should be double-glazed low-E units with a window unit U-value of 0.40 or less as rated by the National Fenestration Rating Council (NFRC) or approved equal.

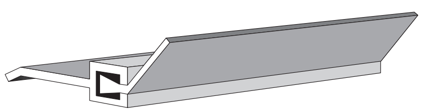
Door measures

Door measures are usually not cost-effective unless they have a very low cost. Doors have a small surface area and their air leakage is more of a localized comfort problem than a significant energy problem most of the time. However, door operation affects building security and durability, so doors are often an important repair priority.

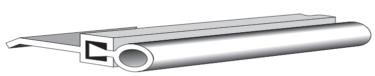
Door weatherstrip, thresholds and sweeps

Door weatherstrip, thresholds and sweeps are marginally cost effective. These measures may be used only if they are found to be cost effective.

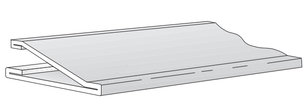




Vinyl flap weatherstrip is particularly flexible, allowing the door to remained sealed with seasonal movements of the door



Silicone bulb weatherstrip is much more flexible than vinyl bulb and therefore seals better.



Bronze v-strip mounts on the door jamb and is very durable.

Weatherstripping doors: Weatherstripping doors is mainly a comfort retrofit. The door should be repaired before weatherstripping by tightening hinges and latches. The door stop should fit tightly against the door when it is closed.

- ✔ Tighten door hardware and adjust stops so door closes snugly against its stops.
- ✔ Use a durable stop-mounted or jamb-mounted weatherstrip material to weatherstrip the door. New weatherstrip must form a tight seal with no buckling or gaps when installed.
- ✔ Plane or adjust the door so it closes without rubbing or binding on the stops and jambs, especially in homes that may have lead paint.
- ✔ Install thresholds and door sweeps if needed to prevent air leakage. They should not bind the door. Thresholds should be caulked at the sill and jamb junction.

Door replacement

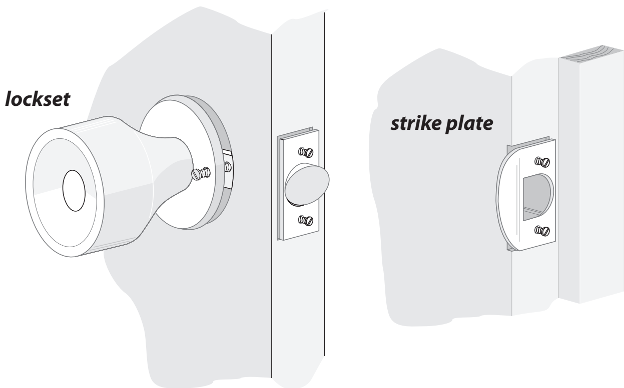
Door replacement is rarely a cost-effective energy conservation measure. Replace a door as an emergency-repair, when the door is damaged beyond repair. Tight uninsulated doors in good condition should *never* be replaced.

Replacement exterior doors must have a solid wood core or an exterior-grade foam core. New wood doors should be sealed to prevent deterioration.

Door repair

Door repair items improve home security and building durability. Door repair can also save energy if the door currently has a poor fit. Limit door repair to these tasks.

- ✔ Replace missing or inoperable lock sets.
- ✔ Reposition the lock set and strike plate.
- ✔ Reposition stops if necessary.
- ✔ Seal gaps between the stop and jamb with caulk.
- ✔ Install a door shoe if needed to repair damage.



Minor door repair: Tightening and adjusting locksets, strike plates, and hinges helps doors work better and seal tighter.

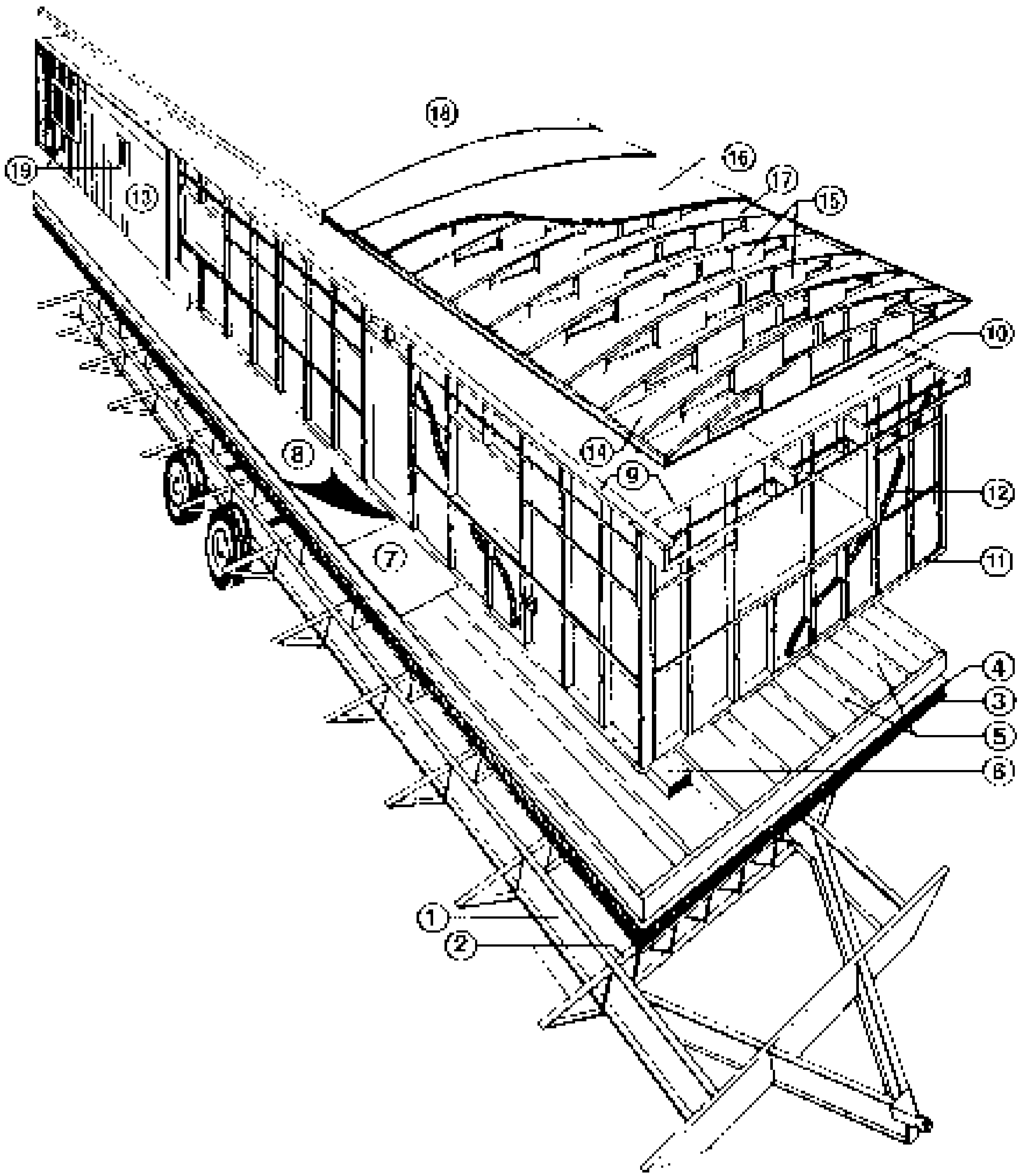
Storm doors

Storm doors and screen doors are expensive per square foot of area and most weatherization programs don't install them because all of the common measures described here are considerably more cost-effective. Storm doors can also damage steel insulated doors on sunny exposures by causing them to overheat.

Section 6 - Mobile Home Standards

Subjects covered in this section

6.1 MOBILE HOME COMPONENTS



Typical Components of a Mobile Home: 1–Steel chassis. 2–Steel outriggers and cross members. 3–Underbelly. 4–Fiberglass insulation. 5–Floor joists. 6–Heating/air conditioning duct. 7–Decking. 8–Floor covering. 9–Top plate. 10–Interior paneling. 11–Bottom plate. 12–Fiberglass insulation. 13–Metal siding. 14–Ceiling board. 15–Bowstring trusses. 16–Fiberglass insulation. 17–Vapor barrier. 18–Galvanized steel one-piece roof. 19–Metal windows.

6.2 Mobile home furnaces

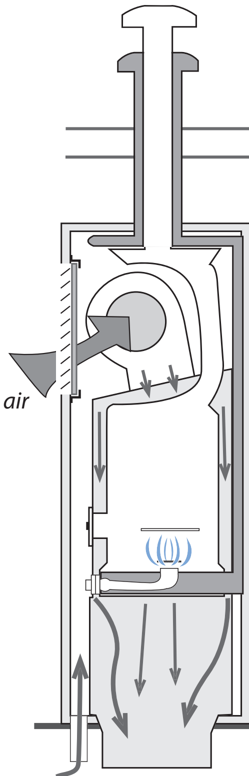
Mobile home furnaces are different from conventional furnaces in several ways.

- A great majority of mobile homes are equipped with downflow furnaces that are designed specifically for mobile homes.
- Mobile home combustion furnaces are sealed-combustion units that use outdoor combustion air, unlike most furnaces in site-built homes. They don't have draft diverters or barometric draft controls.
- Mobile home furnaces require an outdoor source of combustion air.
- Mobile home furnaces have either a manufactured chimney that includes a passageway for combustion air or a combustion-air chute connecting the burner area with the crawl space.
- Gas-fired furnaces have kits attached that contain alternative orifices to burn either propane or natural gas.
- Return air is often supplied to the furnace through a large opening in the furnace cabinet, rather than through ducts connected to the blower compartment.

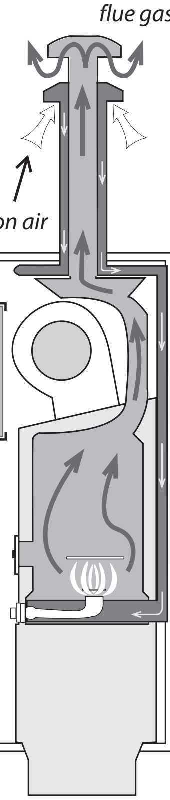
Mobile home furnaces have been sealed-combustion since the early 1970s. Gas furnaces are either the old atmospheric sealed-combustion type or the newer fan-assisted mid-efficiency type. Some older less-efficient sealed-combustion furnaces had draft fans also.

Mobile home oil furnaces are a close relative to oil furnaces in site-built homes. However, they should have a housing that fits around the burner's air shutter and provides outdoor air directly to the burner.

When replacing mobile home furnaces, install only furnaces designed for mobile homes. Always install the complete chimney and roof jack assembly.



Mobile home furnace airflow: Return air flows from the hallway through the furnace grille. The air is heated and distributed through the ducts.



Mobile home furnace combustion: Combustion air enters through the flue assembly on the roof and feeds the flame through a sealed passageway.

Furnace replacement

Mobile home furnaces should be replaced when any of the following is observed.

- The furnace has a heat exchanger which is cracked or rusted through.
- Repair and retrofit exceed half of the replacement cost.
- The furnace is not operating and not repairable.

Mobile home furnaces must be replaced by furnaces designed and listed for use in mobile homes. If a heat exchanger is available to replace the existing cracked heat exchanger, consider heat-exchanger replacement as a repair priority instead of replacing the furnace.

Follow these procedures when installing new mobile home furnaces.

✔ Upgrade the furnace compartment if needed to comply with fire codes.

✔ Install a new furnace base unless you are sure that the existing base exactly matches the new furnace.

✔ Attach the furnace base firmly to the duct, and seal all seams between the base and duct with mastic and fabric tape before installing the furnace.

✔ Support the main duct underneath the furnace with additional strapping if necessary.

✔ Confirm that the home's thermostat is installed on an inside wall and away from drafts, direct heat sources, or direct sunlight.

Mobile-home furnace venting

Mobile-home furnaces are direct-vented, sealed-combustion units that require an outdoor source of combustion air. Mobile-home furnaces may be atmospheric (no draft fan) or fan-assisted. The fan may draw combustion air from a concentric space created by the double-wall chimney or from a duct connected to the ventilated crawl space. Mobile-home furnaces often have a manufactured chimney that includes a passageway for admitting outdoor combustion air supply.

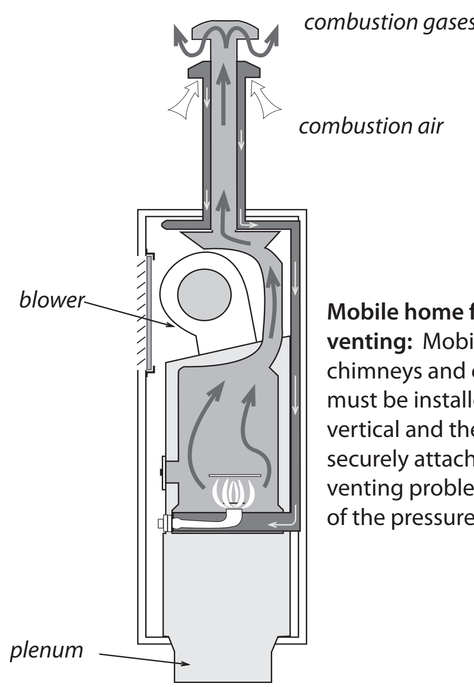
Consider replacing the existing furnace with a sealed-combustion, downflow, condensing furnace. These positive-draft furnaces may eliminate venting and combustion-air problems, common to mobile home furnaces, because of their robust positive draft and negatively pressurized combustion-air vent.

Observe these guidelines for installing mobile home furnace vents.

✔ Note the differences between old and new furnace in the way each is supplied with combustion air.

✔ Install a new chimney that is manufactured specifically for the new furnace. Mobile home furnaces have short chimneys, and their combustion process depends on a delicate balance between combustion air entering and combustion gases leaving. Many callbacks are caused by chimney and chimney-cap alignment.

✔ If the new chimney doesn't exactly line up with the old chimney opening, cut the opening large enough to allow the new chimney to be installed absolutely vertical. Install a ceiling plate to seal the new opening to the chimney. Make sure the chimney cap is installed absolutely level.



Mobile home furnace venting: Mobile home chimneys and chimney caps must be installed perfectly vertical and the cap must be securely attached to avoid venting problems and tripping of the pressure switch.

6.3 Mobile home air sealing

The location and relative importance of mobile home air leaks was a mystery before blower doors. Some mobile homes are fairly airtight, yet many are incredibly leaky. It's recommended that a blower door be used to guide air-sealing work and to check Building Tightness Limits in mobile homes.

For assessing mobile home duct tightness, the blower door used in conjunction with a pressure pan does a good job of detecting air leaks.

Most mobile home duct sealing is performed through the belly. This work is more difficult once the belly has been re-insulated. Inspect the ductwork and seal any major leaks, such as disconnected trunk lines, before insulating the belly.

Table 6.3.1: Mobile home air sealing locations & typical CFM_{50} reduction

Air-Sealing Procedure	Typical CFM_{50} Reduction
Patching large air leaks in the floor, walls and ceiling	200–900
Sealing floor as return-air plenum	300–900
Sealing leaky water-heater closet	200–600
Sealing leaky supply ducts	100–500
Installing tight interior storm windows	100–250
Caulking and weatherstripping	50–150

Mobile home shell air leakage is often substantially reduced when insulation is installed in roofs, walls, and belly cavities. Prioritize your efforts by performing these tasks in this order.

1. Assess the insulation levels. If adding insulation is cost-effective, perform the usual pre-insulation sealing measures that control the travel of insulation.
2. Install cavity insulation. Perform duct sealing first if the belly is to be insulated.
3. Re-check the air leakage rate.
4. Perform additional air sealing as needed.

Shell air-leakage locations

The following shell locations have been identified by technicians using blower doors as the most serious air-leakage sites. Note that window and door air leakage are more of a comfort problem than a serious energy problem.

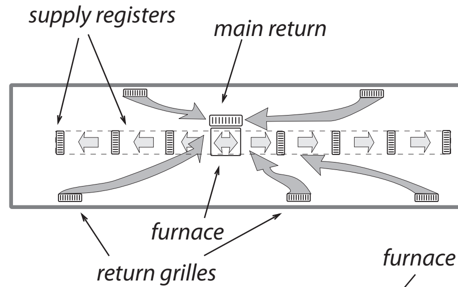
- Plumbing penetrations in floors, walls, and ceilings. Water-heater closets with exterior doors are particularly serious air-leakage problems, having large openings into the bathroom and other areas.
- Torn or missing underbelly, exposing flaws in the floor to the ventilated crawl space.
- Large gaps around furnace and water heater chimneys.
- Severely deteriorated floors in water heater compartments.
- Gaps around the electrical service panel box, light fixtures, and fans.
- Joints between the halves of doublewide mobile homes and between the main dwelling and additions.

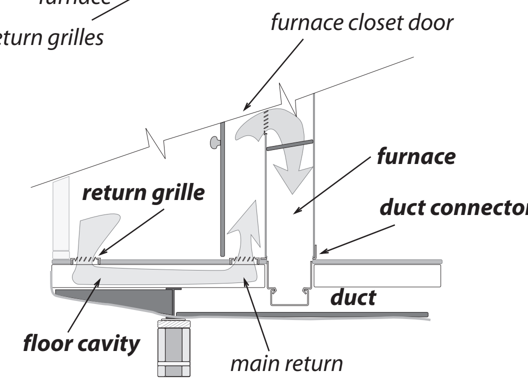
DUCT AIR-LEAKAGE LOCATIONS

The following duct locations have been identified by technicians using blower doors and duct testers as the most serious energy problems.

- Most important is sealing the joints between the furnace and the main duct. The main duct may need to be cut open from underneath to access and seal these leaks between the furnace, duct connector, and main duct. With electric furnaces you can access the supply plenum by removing the bank of resistance elements. For furnaces with empty A-coil compartments, you can simply remove the access panel to access the duct connector.
- Floor and ceiling cavities used as return-air plenums. These return systems should be eliminated in favor of return-air through the hall or a large grille in the furnace-closet door.
- Joints between the main duct and the short duct sections joining the main duct to a floor register.
- Joints between register boots and floor.
- The poorly sealed end of the duct trunk.
- Disconnected, damaged or poorly joined crossover ducts.
- Supply and return ducts for outdoor air conditioner units.
- Holes cut in floors by tradesmen.
- New ductwork added to supply heat to room additions.

Be sure to seal floor penetrations and ductwork before performing any belly repair. Pollutants in the crawl space such as mold, mildew, and fiberglass will be disturbed by repair work, and can be drawn into the home by duct depressurization.



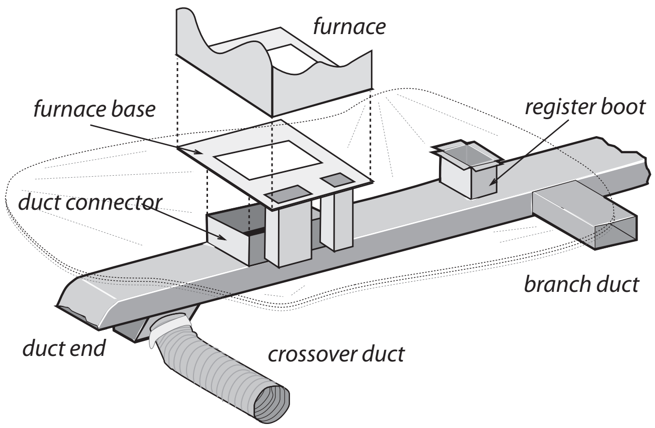


Floor return air: Return-air registers at the floor's perimeter bring air back to the furnace. The floor cavity serves as one big leaky return duct. When leakage is serious, the floor return system should be eliminated.

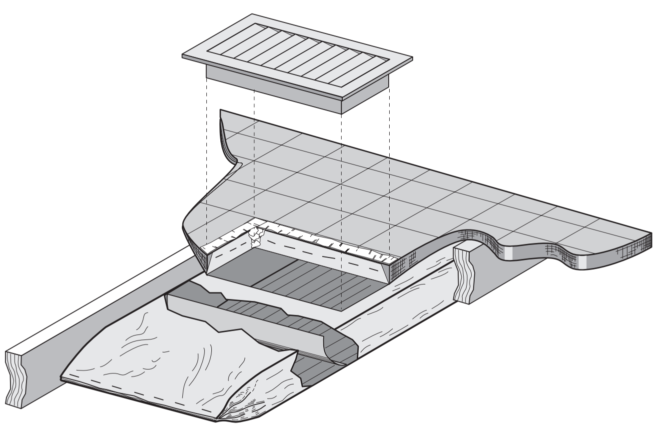
Belly pressure test

Mobile home supply duct leaks tend to pressurize the belly cavity. This rough test can quickly determine if duct leaks are present and their general location.

- ✔ Repair the rodent barrier.
- ✔ Turn on the air handler.
- ✔ Insert a manometer hose into the belly through the rodent barrier, and test the pressure with-reference-to the outdoors.
- ✔ Start near the furnace, and work your way toward the ends alongside the trunk line. A pressure rise will give you a rough idea of the location of leaks, size of leaks, and tightness of the nearby rodent barrier.
- ✔ Repair the ducts and re-test



Mobile home ducts: Mobile home ducts leak at their ends and joints—especially at the joints beneath the furnace. The furnace base attaches the furnace to the duct connector. Leaks occur where the duct connector meets the main duct and where it meets the furnace. Branch ducts are rare, but easy to find, because their supply register isn't in line with the others. Crossover ducts are found only in double-wide and triple-wide homes.)



Sealing the end of the main duct: The main duct is usually capped or crimped loosely at each end, creating a major air leakage point. Seal this area and improve airflow by installing a sheet metal ramp, accessed through the last register, inside the duct. Seal the ramp to the ductwork with metal tape and silicone or mastic.

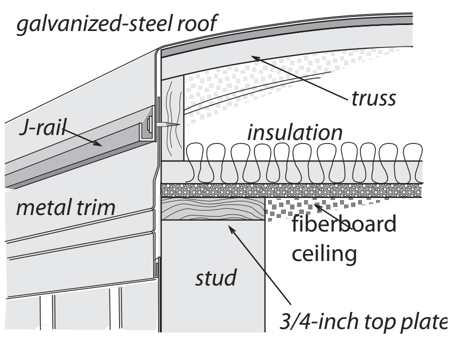
6.4 MOBILE HOME INSULATION

Effective methods for insulating mobile homes have been developed by many weatherization agencies. If your crew is trained in these methods, use the following standards for floor and ceiling insulation.

Address all significant moisture problems before insulating. The most important single moisture-control measure is installing a ground-moisture barrier.

BLOWING MOBILE HOME ROOF CAVITIES

Blowing a closed mobile home roof cavity is similar to blowing a closed wall cavity, only the insulation doesn't have to be as dense. Fiberglass blowing wool is used since cellulose is too heavy and absorbs water too readily for use around a mobile home's lightweight sheeting materials.



Bowstring roof details: Hundreds of thousands of older mobile homes were constructed with these general construction details.

There are three common and effective methods for blowing mobile home roof cavities. The first is cutting a square hole in the metal roof and blowing fiberglass through a flexible fill-tube. The second is disconnecting the metal roof at its edge and blowing fiberglass through a rigid fill-tube. The third involves blowing fiberglass through holes drilled in the ceiling.

Preparing to blow a mobile home roof

Perform these steps before insulating mobile home roofs.

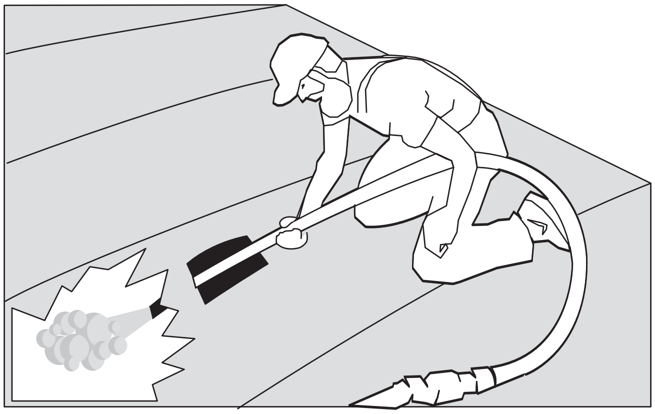
- ✔ Reinforce weak areas in the ceiling.
- ✔ Inspect the ceiling and seal all penetrations.
- ✔ Take steps to maintain safe clearances between insulation and recessed light fixtures and ceiling fans.

Blowing through the top

This approach fills the critical edge area with insulation, and the patches are easy to install if you have the right materials. It is important to complete the work during good weather, however, since the roof will be vulnerable to rain or snow during the job.

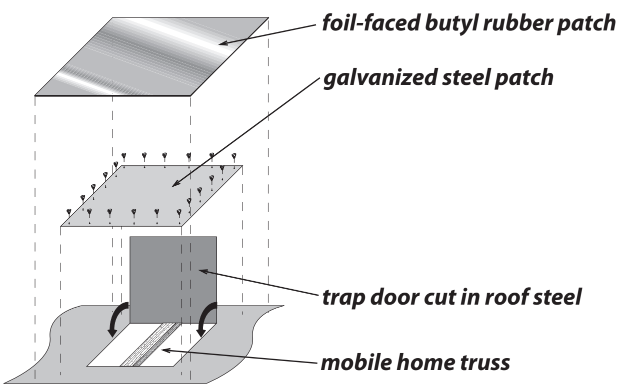
If the roof contains a strongback running the length of the roof, the holes should be centered over the strongback, which is usually near the center of the roof's width. A strongback is a 1-by-4 or a 1-by-6, installed at a right angle to the trusses near their center point, that adds strength to the roof structure.

1. Cut 10-inch square holes at the roof's apex on top of every second truss. Each square hole permits access to two truss cavities.
2. Use a 2-inch or 2-1/$_2$-inch diameter fill-tube. Insert the fill-tube and push it forcefully out toward the edge of the cavity.
3. Blow fiberglass insulation into each cavity.



Roof-top insulation: Blowing fiberglass insulation through the roof top is effective at achieving good coverage and density on almost any metal roof.

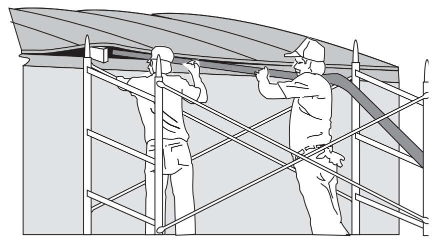
4. Stuff the area under each square hole with a piece of unfaced fiberglass batt so that the finished roof patch will stand a little higher than the surrounding roof.
5. Patch the hole with a 14-inch-square piece of stiff galvanized steel, sealed with roof cement and screwed into the existing metal roof.
6. Cover the first patch with a second patch, consisting of an 18-inch-square piece of foil-faced butyl rubber.



Square roof patch: An 18-inch square of foil-faced butyl rubber covers a base patch of galvanized steel, which is cemented with roof cement and screwed with self-drilling screws.

Blowing a mobile home roof from the edge

This procedure requires scaffold to be performed safely and efficiently. Mobile home metal roofs are usually fastened only at the edge, where the roof joins the wall.



Roof-edge blowing: Use a rigid fill tube to blow insulation through the roof edge. This avoids making holes in the roof itself, though this process requires much care in refastening the roof edge.

1. Remove the screws from the metal j-rail at the roof edge. Also remove staples or other fasteners, and scrape off putty tape.
2. Pry the metal roof up far enough to insert a 2-inch-diameter, 10- to 14-foot-long rigid fill-tube. Two common choices are steel muffler pipe and aluminum irrigation pipe. Inspect the cavity with a bright light to identify any wires or piping that could be damaged by the fill tube.
3. Blow insulation through the fill-tube into the cavity. Turn down the air on the blowing machine when the tube is a couple feet from the roof edge, in order to avoid blowing insulation out through the opening in the roof edge. Or stop blowing a foot or two from the edge, and stuff the last foot or two with unfaced fiberglass batts.
4. Fasten the roof edge back to the wall using galvanized roofing nails, a new metal j-rail, new putty tape, and larger screws. The ideal way to re-fasten the metal roof edge is with air-driven galvanized staples, which is the way most roof edges were attached originally.

Note that re-installation of the roof edge is the most important part of this procedure. Putty tape must be replaced and installed as it was originally. This usually involves installing a layer of putty tape or a bead of high quality caulk under the metal roof and another between the metal roof edge and the j-rail.

The advantages of blowing through the edge is that if you have the right tools, including a powered stapler, this method can be very fast and doesn't require cutting into the roof. The disadvantages of this procedure are that you need scaffolding to work at the edges, and it won't work on roof systems with a central strongback that stops the fill tube from reaching all the way across the roof.

Blowing a mobile home roof from indoors

The advantage to this method is that you are indoors, out of the weather. The disadvantages include being indoors where you can make a mess—or worse, damage something.

This procedure requires the drilling of straight rows of 3-inch or 4-inch holes and blowing insulation into the roof cavity through a fill tube.

Follow this procedure.

1. Drill a 3-inch or 4-inch hole in an unseen location to discover whether the roof structure contains a strongback that would prevent blowing the roof cavity from a single row of holes.
2. Devise a way to drill a straight row of holes down the center of the ceiling. If a strongback exists, drill two rows of holes at the quarter points of the width of the ceiling.
3. Insert a flexible plastic fill tube into the cavity, and push it as far as possible toward the edge of the roof.
4. Fill the cavity with tightly packed fiberglass insulation.
5. Cap the holes with manufactured plastic caps. Care must be taken not to damage the holes so that the plastic hole covers fit properly. You can also install a piece of painted wood trim over the line of holes.

Mobile home roof caps

An insulated synthetic rubber roof cap significantly reduces winter heat loss and summer heat gain through a roof. Follow the manufacturer's instructions carefully. If installed with excellent workmanship, the membrane could last 50 years. With poor workmanship, the membrane could leak in 10 years or less.

Although black is the most common and least expensive type of rubber roofing, a bright white rubber is preferred. Black roofs get hot and the heat could shrink the insulation. Especially in warm climates, white rubber roofing is worth the extra cost.

With insulated rubber roofing systems, insulation board—polyurethane foam or polystyrene foam—is installed directly over the existing roof and then covered by rubber roofing material. These are general instructions to let you know what's involved. Follow the specifications and instructions of the roofing manufacturer carefully when you actually install the roof. Following are general installation instructions.

1. Remove existing plumbing and heating vents protruding from the roof; also remove the vent flashings around these protrusions. Remove roof-mounted evaporative coolers and raise their mounting blocks above the level of the new roof. The new roof level equals the old roof level plus the thickness of the insulation and the rubber roofing. If there isn't any solid surface around the chimney underneath the existing metal roofing, fasten plywood squares to the existing roof surface around the chimney to provide a wood backer for fastening the chimney flashing through the new roofing and insulation.
2. Fasten the insulation board to the roof trusses using screws long enough to penetrate into the truss 1/2-to-1 inch. Use large washers, called fender washers or roof deck plates, to prevent the screws from pulling through the insulation. Cut the insulation to fit around all the vent holes. Leave at least 3 inches clearance around hot vents like wood stove flues. Stuff fiberglass around pipes and vents to insulate spaces left by mis-cuts or spaces intentionally left for fire safety clearance (heat shouldn't be a problem here—fiberglass is noncombusti-

ble and all legal chimneys are double- or triple-wall).

3. Lift the leading edge of the membrane over the edge of the roof and drag it up onto the roof. This is a job for two-to-four people. Spread the membrane out so that at least 6-inch overhangs on all sides. Then locate all the vent holes and cut openings in the membrane for each vent.

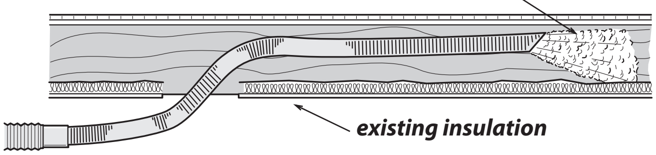
4. Extend plumbing, heating and exhaust vents at least 10 inches above the new roof level. Fabricate or buy new rubber flashing for around the vent pipes. New flashings can be purchased from a roofing-materials dealer or fabricated from rubber membrane on-site. Apply the membrane's special contact adhesive to the back of the flashing. It is important to apply this adhesive evenly and continuously. It is also important to keep the rubber membrane around penetrations clean during the flashing installation. After the contact-type adhesive dries, adhere the flashing, seal all seams and edges of the membrane and flashing on the roof with a special seam sealant. Remember that most roof leaks occur at seams and flashings: Careful adhesive application and seam sealing will determine how long the roof will keep water out.

5. Install the new termination bar just above or below the existing j-rail at the junction between the roof and wall. Begin at the center on both long sides of the roof and work towards the ends of the roof, driving sheet metal screws into the termination bar's pre-drilled holes. Straighten the membrane and work out any wrinkles as you proceed. Do not fasten the termination rail the last 1-to-2 feet at the corners until you have folded the corners of the rubber roofing (see Step 6). Follow the same procedure for the ends of the roof. Begin in the center and work towards the corners. Again, do not fasten the termination rail the last 1-to-2 feet at the corners until you have folded the corners (see Step 6).

6. Fold the membrane at each corner so that the crease faces downward. Fasten the last 1-to-2 feet of the termination rail. Then, trim off the excess membrane hanging below the new termination rail.

Mobile home floor insulation

Mobile home floor insulation is a good energy-saving measure in cool climates. The original insulation is usually fastened to the bottom of the floor joists, leaving much of the cavity uninsulated and subject to convection currents. This greatly reduces the insulation's R-value. Blown-in belly insulation also tends to control duct leakage.



Blowing bellies: A flexible fill-tube, which is significantly stiffer than the blower hose, blows fiberglass insulation through a hole in the belly from underneath the home.

Preparing for mobile home floor insulation

Prior to installing floor insulation, always perform these repairs.

- ✔ Repair plumbing leaks.
- ✔ Tightly seal all holes in the floor.
- ✔ Inspect and seal ducts.
- ✔ Repair the rodent barrier.
- ✔ Install a ground-moisture barrier in the crawl space if the site is wet.

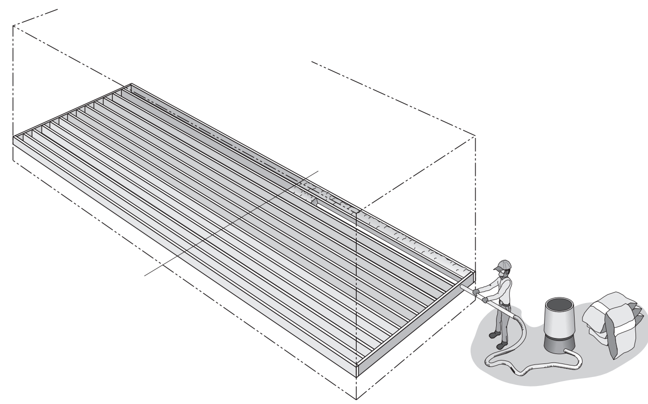
Insulating the floor

Two methods of insulating mobile home floors are common. The first is blowing fiberglass insulation through a flexible fill tube from holes in the underbelly. The second is drilling through the 2-by-6 rim joist and blowing fiberglass through a rigid fill tube.Blown fiberglass is recommended over cellulose for either method.

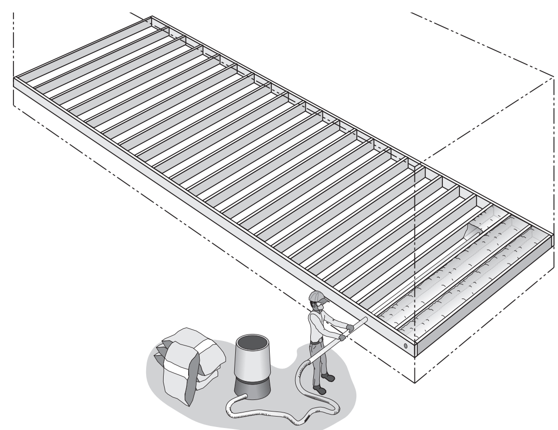
First repair all holes in the belly. Use mobile home belly-paper, silicone sealant, and stitch staples. Use these same patches over the holes cut for fill-tubes. Screw wood lath over weak areas if needed. When blowing through holes from underneath the home, consider blowing through damaged areas before patching them.

Identify any plumbing lines, and avoid installing insulation between them and the living space if freezing could be an issue. This may require running a piece of belly-paper under the pipes, and insulating the resulting cavity, to include them in the heated envelope of the home.

Unfaced fiberglass batts may also be used to insulate floor sections where the insulation and belly are missing. The insulation should be supported by lath, twine, or insulation supports. This is a good approach when it is not cost-effective to insulate the entire belly.



Blowing lengthwise cavities: Floors with lengthwise joists can rarely be filled completely from the ends because of the long tubing needed. The middle can be filled from underneath.



Blowing crosswise cavities: Blowing insulation into belly is easy if the floor joists run crosswise. However, the dropped belly requires more insulation than a home with lengthwise joists.

Mobile home skirting

The primary purpose of skirting is to keep animals out of the crawl space. Skirting must be vented to reduce moisture accumulation in many climates, so there isn't much value in insulating it.

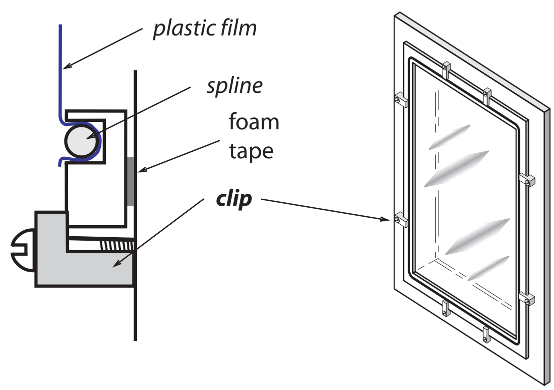
Installation and repair of mobile home skirting is seldom cost-effective. Instead, try to locate the thermal boundary at the floor of mobile homes.

6.5 MOBILE HOME WINDOWS AND DOORS

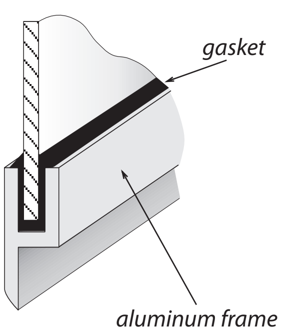
Replacing windows and doors is generally not cost-effective and should only be done if repairs cannot hold the window or door together any longer.

New jalousie or awning windows are not acceptable as replacements because of their high infiltration rates. Replacement windows with an emergency release are available, and these should be used when replacing windows in bedrooms.

MOBILE HOME STORM WINDOWS



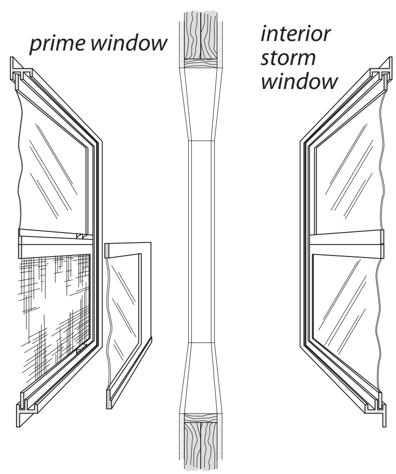
Plastic storms: Some newer storm-window designs use a lightweight aluminum frame and flexible or rigid plastic glazing.



Glass interior storms: Traditional mobile home storm windows have aluminum frames glazed with glass.

Interior storm windows are common in mobile homes. These stationary interior storms serve awning and jalousie windows. Sliding interior storm windows pair with exterior sliding prime windows.

- Interior storm windows double the R-value of a single-pane window. They also reduce infiltration, especially in the case of leaky jalousie prime windows.
- Avoid replacing existing storm windows unless the existing storm windows cannot be re-glazed or repaired.
- When sliding primary windows are installed, use a sliding storm window that slides from the same side as the primary window. Sliding storm windows stay in place and aren't removed seasonally, and are therefore less likely to be lost or broken.



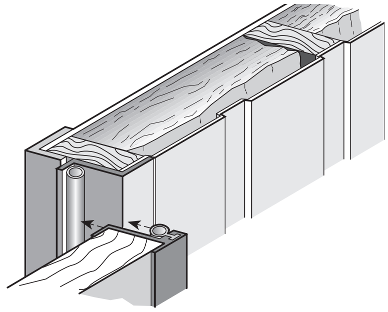
Mobile home double window: In mobile homes, the prime window is installed over the siding outdoors, and the storm window is installed indoors.

REPLACING MOBILE HOME WINDOWS

Inspect condition of rough opening members before replacing windows. Replace deteriorated, weak, or waterlogged framing members.

Prepare replacement window by lining the perimeter of the inner lip with $^1/_8$-inch thick putty tape. Caulk exterior window frame perimeter to wall after installing window.

Mobile home doors



Mobile home door: Mobile home doors swing outwardly and have integral weatherstrip.

Mobile home doors come in two basic types: the mobile home door and the house-type door. Mobile home doors swing outwardly, and house-type doors swing inwardly. Door replacement is an allowable expense only when the existing door is damaged beyond repair and constitutes a severe air-leakage problem.

A–1 Tools for Air Sealing and Insulating

Insulation blower	Broom and dust pan
Blower hoses 4, 3, & 2.5 inch	Cat's paw
Fill tubes and hose fittings	Caulking guns
Coveralls and gloves	Chisels: cold and wood
First-aid kit	Cleaning fluid and rags
Hard hat	End nippers
Respirators and filters	Flashlight
Safety glasses	Hack saw and blades
Ext. ladders, leveler, & hooks	Hammers and wrecking bars
Portable lights	Hand saws
Scaffold, planks, and handrail	Hand staplers
Step ladders: 4, 6, & 8 foot	Metal & Vinyl-siding zip tools
Circular saw with blades	Mirror
Compressor and power stapler	Pliers: electrical & slip-joint
Drill index with bits	Putty knives and scrapers
Drills, drivers, and bits	Putty warmer
Extension cords	Scratch awl and pin punches
HEPA vacuum with attachments	Steel tape measures
Lead paint drill shroud	Screw drivers and nut drivers
Reciprocating saw with blades	Squares: frame, combo, drywall
Shop vacuum, hoses, attachments	Tin snips: hand and electric

A–2 Tools for Auditing and Mechanical

Coveralls and gloves Safety glasses	Clipboard box, writing supplies, pencils Steel tape measures
Blower door Digital manometer with hoses Pressure pan Heat-exchanger test kit Digital combustion analyzer Digital CO detector Digital thermometer with ΔT Moisture meter Remote viewer	Adjustable wrenches Cold chisels and wood chisels Flash lights and portable lights Flexduct strap tightener Hack saw and blades Inspection mirror Pipe wrenches Pliers: electrical & slip-joint Screw drivers, nut drivers, and bits Sheet-metal crimper Tin snips Sockets and ratchet Wire and bristle brushes
Non-contact voltage detector Volt-ohmmeter Recording watthour meter Plug-in circuit tester Wire strippers	Cordless drill-driver Drill index with bits
Auditing software Calculator	Hand truck

A–3 Weatherization Materials

Cellulose	Assorted wire nuts and electrical connectors
Closed-cell foam tape	Compact fluorescent lamps
Fiberglass batts	Energy-saving shower heads
Fiberglass blowing wool	Programmable thermostats
Fiberglass duct wrap	Replacement fan controls
Foam backer rod	Replacement furnaces
Foam pipe sleeves	Replacement refrigerators
One-part squirt foam	Replacement water heaters
Sheet foam insulation	1/4-inch plywood or hardboard
Two-part spray foam	Assorted lumber
Water heater insulation	Assorted screws and nails
Assorted chimney pipe	Assorted staples
Assorted furnace filters	Construction adhesive
Duct mastic and web tape	Disposable coveralls, boot covers, and
Duct tape and electrical tape	Disposable paint brushes
Furnace filter material	Plastic garbage bags
Proper vents	Plastic sheeting
Sheet metal	Pop riveter
Acoustical sealant	Putty tape
Bronze v-seal weatherstrip	Silicone or urethane caulk
Jamb-up weatherstrip	Siliconized acrylic-latex caulk
Client-education booklets	Portable tape recorder

A–4 R-VALUES FOR COMMON MATERIALS

Material	R-value
Fiberglass or rock wool batts and blown 1″	2.8–4.0[a]
Blown cellulose 1″	3.0–4.0[b]
Vermiculite loose fill 1″	2.7
White expanded polystyrene foam (beadboard) 1″	3.9–4.3[a]
Polyurethane/polyisocyanurate foam 1″	6.2–7.0[c]
Extruded polystyrene (blue, yellow or pink) 1″	5.0
Oriented strand board (OSB) or plywood $^1/_2$″	1.6
Concrete 1″	0.1
Wood 1″	1.0[d]
Fired clay bricks 1″	0.1–0.4
Gypsum or plasterboard $^1/_2$″	0.4
Single pane glass	0.9
Low-e insulated glass	3.3–4.2[e]
Triple glazed glass with 2 low-e coatings	8.3

a. Varies according to density (increases with increasing density).
b. Varies according to density (decreases with increasing density).
c. Varies according to age and formulation.
d. Varies by species.
e. Varies according to Solar Heat Gain Coefficient (SHGC) rating.

A–5 RESOURCES

ASHRAE 1993 Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc; Atlanta GA 1993

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Insulate and Weatherize, by Bruce Harley, Taunton Press, 2002

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MWX90: Minnesota Low Income Weatherization Procedure for the 1990s, by Lester Shen, December 1993, Underground Space Center

Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger and Chris Dorsi, Fourth Edition, 2004

Weatherization Standards, Illinois Home Weatherization Assistance Program, with John Krigger, First Edition, 1999

Weatherization Training Manual for Housing Technicians I & II, by John Krigger, First Edition, 1997

Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger, Fourth Edition, 1998

ENERGY

OutWest

A Holistic Approach